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# Permian Brachiopods of West Texas III,

(PART 1 — TEXT)

G. ARTHUR COOPER  
and  
RICHARD E. GRANT





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# Permian Brachiopods of West Texas, III

(PART 1 - TEXT)

*G. Arthur Cooper*  
*and Richard E. Grant*

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## ABSTRACT

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# Permian Brachiopods of West Texas, III

*G. Arthur Cooper and Richard E. Grant*

## Order STROPHOMENIDA Öpik, 1934

### Suborder PRODUCTIDINA Waagen, 1883

### Superfamily STROPHALOSIACEA Schuchert, 1913

### Family STROPHALOSIIDAE Schuchert, 1913

Primitive Strophalosiacea with hinge teeth in the pedicle valve and sockets in the brachial valve. Pedicle valve having an interarea; delthyrium closed by a flat or convex pseudodeltidium. Notothyrium, if present, covered by a chilidium. Pedicle valve anchored by rhizoid spines and umbonal cementation. Cardinal process initially bilobed but becoming trilobed to bulbous with age.

### Subfamily STROPHALOSIINAE Schuchert, 1913

Strophalosiidae having a smooth dorsal valve, without spines.

Genera in West Texas: *Strophalosia* W. King (1844) is extremely rare in West Texas, only four specimens having been found; *Heteralosia* is a genus common in West Texas in the Permian and Pennsylvanian.

Muir-Wood and Cooper (1960) erroneously described the subfamily Strophalosiinae as having a spiny dorsal valve. They then created the Hetera-

losiinae for genera of strophalosiids having a dorsal valve without spines. Brunton (1966) studied the type specimens of *Strophalosia gerardi* W. King, type-species of the genus, and was unable to find any trace of spines on its dorsal valve. He therefore recommended the elimination of the Heteralosiinae. *Heteralosia* proves to be different generically from *Strophalosia* but belongs in the same family.

### Genus *Strophalosia* W. King, 1844

### *Strophalosia inexpectans*, new species

PLATE 269: FIGURES 13-30

Medium size, but large for genus, wider than long, subquadrate in outline; concavo-convex; sides moderately rounded, greatest width at midvalve; hinge narrower than midwidth, straight, with short interarea. Anterior margin rounded to somewhat truncated medially. Rhizoid spines short and delicate, concentrated on ears, umbonal, and postero-lateral slopes; ornament spines numerous, delicate, recumbent, covering entire surface.

Pedicle valve fairly evenly and moderately convex in lateral profile; anterior profile broadly convex, moderately steep lateral slopes. Umbonal region swollen moderately but extended slightly posterior to posterior margin. Median region greatly swollen, long anterior slope moderately swollen but not steep. Interarea orthocline. Delthyrium small and narrow and covered by a slightly convex pseudodeltidium. Ears poorly developed, obtuse. Cicatrix of attachment small.

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Brachial valve not well known, moderately concave; deepest posteromedially; posterolateral regions flattened; interarea short, hypercline. Ornament spines thin and delicate.

Pedicle valve interior with small, delicate teeth very closely spaced. Adductor scars large and rounded; diductor scars flabellate and surrounding adductors.

Brachial valve interior with long narrow cardinal process extending nearly perpendicular to posterior margin. Sockets deep. Adductor scars elongate; median ridge low, rounded, extending to base of cardinal process and to about midvalve in anterior direction.

MEASUREMENTS (in mm).—

	length	brach- ial valve length	sur- face length	mid- width	hinge width	height
AMNH 512						
151229a	26.9	23.0	33.0	30.0	20.0	10.6
151229b	23.6	20.5	28.0	30.4	22.0	9.5
(holotype)						
151229c	23.4	19.4	27.0	27.3	20.8	8.0

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member).

LOCALITY.—AMNH 512 (= USNM 728).

DIAGNOSIS.—Large *Strophalosia* with numerous fine recumbent hairlike spines on the brachial valve and short rhizoid spines on the ears.

TYPES.—Holotype: USNM 151229b. Figured paratypes: USNM 151229a, c, d. Measured paratypes: USNM 151229a, c.

COMPARISON.—No other strophalosiid of this type is now known from North American Permian rocks. The genus *Strophalosia*, sensu stricto, appears hitherto to have been restricted to the Permian of Asia and Australia. Some species have been described from the latter place and the type of the genus is from the Himalayas but it is poorly known. Species from Australia usually assigned to *Strophalosia* have a spinose brachial valve, a feature shared with *S. inexpectans*.

*Strophalosia inexpectans* cannot be compared favorably with any of the Australian species which are much larger and more robust, usually with stronger spines and with details of the interior different from those of the Guadalupe Mountains species. The Australian strophalosias usually have the cardinal process thick-shafted but the median

ridge is not strongly developed. A platform for the ventral adductor muscles is usually present in these austral species. *S. gerardi* W. King, the type species of the genus, is also a large form very similar to the Australian species but its interior is unknown. The American species is wider-hinged than any of the species figured by Coleman (1957).

DISCUSSION.—This species is known from only four specimens, three pedicle valves and one fragmentary brachial valve. Considering the enormous quantity of material from AMNH 512 = USNM 728 dissolved by the two institutions, this proves to be one of the rarest species in the Guadalupe Mountains. It is of special interest as the first representative of the genus to be found on this continent.

Genus *Heteralosia* R. H. King, 1938

*Heteralosia hystricula* (Girty)

PLATE 193: FIGURES 45, 46; PLATE 194: FIGURES 16–31; PLATE 195: FIGURES 1–43

*Strophalosia hystricula* Girty, 1909:275, pl. 30: figs. 14, 14a. [Not of R. E. King, 1931:96.]

Small, subcircular in outline, lateral and anterior margins rounded; hinge narrower than greatest width at midlength. Commissure without fold; pedicle valve adorned by rhizoid and ornament spines, rhizoid spines in row along hinge, numerous on ears, and scattered distantly over entire surface. Ornament spines stout and recumbent, usually short, many lying closely and irregularly along valve surface, those on valve edge usually longer and attaining length about 7 mm. Brachial valve marked by small dimples and mounds.

Pedicle valve strongly and evenly convex in lateral profile, broadly domed in anterior profile; cicatrix of attachment large, usually occupying entire umbonal region. Median region strongly inflated; lateral and anterior slopes steep; ears minute, poorly defined; interarea short, broadly triangular, flat, covered by slightly elevated pseudo-deltidium. Teeth small, long, about 1 mm. or less apart. Adductor field small, elevated to form subtriangular callosity with central longitudinal ridge or carina; adductor callosity in old individuals partially excavate. Diductor scars large, surrounding adductor field and occupying about posterior half of valve.

Brachial valve irregular but generally moderately concave, umbonal region slightly convex. Anterior margin somewhat abruptly reflected dorsally. Interior with laterally compressed cardinal process, lobes of myophore separated only by narrow groove in anteroventral face in young, but varying with age to bilobed and trilobed. Sockets deep, floored by small horizontal plates and roofed by extensions of palintrope. Adductor field subcircular, small, divided by thin but low median septum extending slightly anterior to midvalve.

MEASUREMENTS (in mm).—

	length	brach- ial valve length	hinge width	maxi- mum width	height	thick- ness
USGS 3763						
118545	10.0	?	8.3	11.7	4.7	?
(holotype)						
USNM 706e						
152629a	12.9	?	12.3	15.9	5.5	?
152629b	11.4	?	10.6	13.3	5.1	?
152629c	11.0	7.9	6.8	11.7	3.4	?
152629e	?	8.0	11.0	11.0	?	?
USNM 706b						
152630a	10.4	9.0	8.5	12.1	4.6	2.6
152630b	10.9	8.4	8.6	12.9	4.6	2.7
152630c	8.4	6.8	7.3	10.5	4.2	2.2
152630d	7.4	5.7	5.2	7.8	3.0	1.6
152630e	11.0	9.8	8.2	13.3	5.0	4.3
152630g	11.9	?	10.7	14.6	6.7	?

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation, Word Formation (China Tank, Willis Ranch, Appel Ranch members and lenses between the last two), Cherry Canyon Formation.

LOCALITIES.—Road Canyon: USNM 703c, 716xa, 721j, 721z, 723w, 724c. Word: USGS 3763; USNM 732s. China Tank: USNM 703e, 706a, 706c, 706z, 713, 726r, 733q. Willis Ranch: AMNH 505, 506; USNM 706, 706e, 723t, 724u, 735c. Appel Ranch: 704, 706d, 714o, 715i, 719z, 726t. Lenses: 706b, 732c. Cherry Canyon: USNM 728.

TYPES.—Holotype: USNM 118545. Figured hypotypes: USNM 123891g; 153581b; 154115a–l; 154116a–f; 154117a, c; 154118a–e. Measured hypotypes: USNM 152629a–c, e; 152630a–e, g.

DIAGNOSIS.—Subcircular, moderately large *Heteralosia* with numerous stout rhizoid spines.

COMPARISON.—No foreign or North American species is like *H. hystricula* (Girty). The Salt Range species described by Reed (1944) are mostly much larger and not comparable. In North America *H.*

*mexicana* Cooper, which comes from beds of about the same age as the Glass Mountains species, is larger and is less convex and somewhat subquadrate rather than circular.

DISCUSSION.—The spines, muscle area of the pedicle valve, and the cardinal process are anatomical features of *H. hystricula* that need elaboration. In most specimens the rhizoid or attachment spines are confined to the cardinal extremities and the posterior margin. As in other attached forms the young stages of this species are fixed to their anchorage by a fringe of rhizoid spines around the margin of the cicatrix. These spines are sufficient to fix the young forms, but the larger specimens need additional anchorage. This is accomplished by rhizoid spines given off at almost any point on the anterior slope of the pedicle valve. These spines are scattered among the prostrate ornament spines. They are given off at about right angles to the shell surface and are extended toward the substratum and grow until contact is made. They are extended along the surface of the object of attachment for a distance sufficient to accomplish their purpose.

The rhizoid and ornament spines can be distinguished readily on exfoliated shells. The ornament spines are given off from the shell surface obliquely but early turn at an angle to grow almost parallel to the surface. Shells found loose on the outcrop or broken from rock have many of the spines stripped off. Most of the rhizoid spines are destroyed but the ornament spines are only partially stripped away because they so closely follow the surface slope. The bases of the stripped off rhizoid spines show as small circular holes but the bases of the ornament spines usually consist of the angularly bent proximal end.

The part of the muscle area of the pedicle valve of interest is that concerned with the adductor muscles. In young specimens the adductor scars appear on each side of a low, linear, scarcely perceptible, median ridge located just under the delthyrium and extending anteriorly for about one-quarter valve length. With advancing age and size this muscle region is gradually thickened, but the increase in thickness is uneven. Most of the thickening takes place medially and emphasizes the height of the median myophragm. The area in question becomes triangular in outline, the base of the triangle being the truncated anterior margin of the adductor field. With advancing age the anterior of



this triangular callosity is excavated to form a somewhat tentlike plate. The excavation is seldom deep into the callosity, but, nevertheless, may be conspicuous.

Inside the brachial valve the cardinal process goes through interesting changes with growth. Normally the shaft of the cardinal process of the adult is short, with the myophore extending obliquely posteriorly at a low angle to the commissure. The myophore is laterally compressed and narrow, usually with a narrow median depression that divides it into two lobes. On the anteroventral face the cardinal process also displays a fine median depression, in many specimens widening slightly to indent the distal end of the myophore and emphasize its bilobed character. On the myophore a roughened area (muscle scar) appears on each side of the median depressed line. This is slightly elevated above the margins. In old specimens the median roughened area is expanded and is set off from the lateral depressed areas by deep grooves. This arrangement produces a trilobed cardinal process, the median roughened area bounded by depressed lateral lobes. In a few specimens, however, the median roughened lobe is divided by a deep depression and it becomes bilobed. This, with the lateral lobes, produces a quadrilobed cardinal process.

The shaft of the cardinal process usually is slightly thickened at the base where the sockets are located. With age, strong horizontal ridges may appear at the base of the cardinal process, just anterior to and bounding the sockets. In other old specimens a ridge or thickening may be developed on the anterior margins of the adductor field to form a chevron-shaped ridge with its apex anchored in the median septum dividing the adductor scars.

**GROWTH.**—As usual in attached shells of this type the cicatrix of attachment is fairly large, attaining 6 mm. in some specimens. Consequently, the young shell is flat and spread out before it geniculates and starts to grow with the anterior part nearly vertical. The adult shell is strongly erect on its attachment surface. The plane of commissure is nearly that of a right angle and inclination from the vertical may take place to produce either an acute or an obtuse angle.

**VARIATION.**—Like all brachiopods that are fixed by part of their shell, *H. hystricula* is affected in

form, size, and ornament depending on the conditions under which it grew. Specimens obviously adult or in old age status are dwarfed because of growth against an impeding object. The hinge is a variable part of this species because of impingement against objects or because of distortion by growing on uneven surfaces. In spite of all these difficulties the species generally maintains its strong convexity and the characteristic spinosity.

**ECOLOGY.**—*Heteralosia hystricula* apparently attached to any solid object with which the larvae came in contact. It is found on nearly all of the common Word brachiopods, small or large, on some of the pelecypods, and on corals and bryozoans. *Paucispinifera*, probably because it is very abundant, is commonly encrusted by *H. hystricula*.

**REMARKS ON STRATIGRAPHY.**—The type-specimen of *Heteralosia hystricula* was collected by R. T. Hill and is said to come from the "Deleware Mountain Formation, Comanche Canyon, Glass Mountains, Texas (station 3763)." The specimen has the appearance of a Word fossil and is believed to have come from the Word Formation, probably Word (Third Limestone Member of P. B. King = Willis Ranch Member).

We have assigned specimens from some localities in the Road Canyon Formation to this species. These have about the same convexity and general form, and the body spines in length and thickness are like those of *H. hystricula*. Much larger collections are needed before a distinction between these specimens and Girty's species could be established. *Heteralosia*, however, has proved to be rare outside of the China Tank and Willis Ranch members.

### *Heteralosia magnispina*, new species

PLATE 192: FIGURES 11–19; PLATE 193: FIGURES 12, 13; PLATE 196: FIGURES 43–67

Moderate size, subcircular to subquadrate outline, hinge narrower than greatest width (at mid-valve); sides and anterior margins rounded. Cicatrix variable. Pedicle valve with large, thick rhizoid spines; ornament spines prostrate but stout and distant.

Pedicle valve strongly convex in lateral and anterior profiles; median region strongly inflated; lateral and anterior slopes steep; interarea flat, short; teeth small, elongate, closely spaced. Adductor ridge moderately long but not strongly elevated.

Brachial valve with posterior half corresponding to cicatrix, flat to gently convex; anterior half, concave; surface irregularly and coarsely dimpled or irregularly folded. Cardinal process small and delicate; myophore variable but not greatly thickened. Shaft stout at base and buttressed by slender lateral plates anterior to sockets. Median septum thick at junction with cardinal process, becoming a slender and delicate partition anteriorly and extending to just beyond midvalve. Adductors with prominent V-shaped ridge on anterior side in adults. Surface, especially in anterior third, marked by fine endospines.

MEASUREMENTS (in mm).—

	length	brach- ial valve length	hinge width	maxi- mum width	thick- ness	height
USNM 728						
151272a	7.3	?	5.6	7.3	?	3.5
151272b	7.9	?	6.8	8.0	?	4.0?
151272c	7.4	5.9	7.5	8.5	2.8	3.9
151272d	8.0	?	6.1	8.5	?	3.1
151272e	8.5	?	10.0	10.4	?	3.8
(holotype)						
151272f	?	6.4	6.7	7.5	?	?
151272g	?	7.4	9.0	9.6	?	?
151272h	?	6.2	6.8	7.5	?	?

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member), Bell Canyon Formation (Hegler, Pinery, Rader, McCombs and Lamar members).

LOCALITIES.—Getaway: AMNH 21, 512, 519, 600; USNM 728, 730, 732. Hegler: AMNH 635; USNM 731, 732a. Pinery: AMNH 375, 528; USNM 725h, 725n, 733. Rader: AMNH 404, 410; USNM 725f, 725g, 740a, 740i. McCombs: AMNH 385. Lamar: AMNH L-6, 37, 430; USNM 725a, 728i, 728p, 738, 738b. Unplaced: AMNH 524.

DIAGNOSIS.—Strongly convex *Heteralosia* with strong rhizoid spines and distant, coarse ornament spines. Cardinalia delicate.

TYPES.—Holotype: USNM 151272e. Figured paratypes: USNM 151272c, d, f-l, 0; 151289a, b; 154119. Measured paratypes: USNM 151272a-d, f-h. Unfigured paratypes: USNM 151272a, b, d; 151289c.

COMPARISON.—This species somewhat suggests *H. hystricula* (Girty) but differs in having fewer and stronger spines of both types on the pedicle

valve and generally more delicate structures in the brachial valve. The cardinal process is shorter than that of the Glass Mountains species but the septum is continuous and more prominent in the Guadalupe Mountains species.

DISCUSSION.—The collection on which this description is based is mainly from the Getaway Member (AMNH 512=USNM 728) which contains adequate series. Specimens from other localities are few. Several specimens have finer spines than the majority but even these spines are coarser and less numerous than those of *H. hystricula*. Specimens from the Bell Canyon Formation usually consist of a few each from many localities and variation among them is considerable. Nevertheless, when they are compared with the standard set from the Getaway Member, we are unable to find any consistent differences. The body or ornament spines are of the same size and abundance but the profiles and shapes are extremely variable. This, however, is characteristic of cemented forms. Several specimens (lot USNM 151289) of brachial valves have a bizarre development of the so called brachial ridges in which they are elevated anteriorly from the valve floor and simulate those of *Xenosteges*.

The ecology of this species seems to be identical to that of *H. hystricula* but it may have lived in more strongly moving water, accounting for the large and thick anchor spines and the fair abundance of specimens stripped off their moorings.

*Heteralosia paucispinosa*, new species

PLATE 193: FIGURES 26, 27; PLATE 196: FIGURES 1-42

Small, subcircular outline, hinge narrower than maximum width; anterior well rounded; cardinal extremities obtuse; cicatrix moderately large; interarea moderately long; rhizoid spines stout, in ring around cicatrix; ornament spines few, long and stout, attaining length of 5 mm on anterior margin. Spines borne on poorly defined costae.

Teeth small; delthyrium narrow, not covered; median range varying from absent to a thin septum; muscle scars not seen.

Brachial valve with anterior half wrinkled and pitted, moderately concave; interarea short, steeply inclined. Interior with narrow, strongly elevated cardinal process, not strongly lobate; median ridge low; adductor field slightly thickened.

## MEASUREMENTS (in mm).—

	length	brach- ial valve length	maxi- mum width	hinge width	height
USNM 731					
154129c (holotype)	10.6	8.7	9.4	6.6	3.5
154129b	?	9.5	11.2	8.6	4.0
154129e	8.8	8.0	8.8	6.3	4.2

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler, Pinery, Rader and Lamar members).

LOCALITIES.—Pinery: AMNH 401. Hegler: USNM 731, 732a, 740c, 740d. Rader: USNM 740a, 740j. Lamar: AMNH 38.

DIAGNOSIS.—Small *Heteralosia* with a few very strong and long spines.

TYPES.—Holotype: USNM 154129c. Figured paratypes: USNM 151280a–c; 154129a, b, d–g; 154130; 154131a, b; 154132a, b; 154133; 155030.

COMPARISON.—This species differs from all the others described herein by its few strong spines and circular outline.

DISCUSSION.—As with all *Heteralosia* this species is very variable, but its strong spines and considerable depth help to identify it. Specimens from AMNH 38 show an unusually deep and thick pedicle valve with a moderately thickened diductor region. In the brachial valve the so-called brachial ridges are elevated anteriorly like those of *Xenosteges*. Specimens larger than usual in the Hegler Member were taken in the Rader Member, USNM 740a.

*Heteralosia tenuispina*, new species

PLATE 193: FIGURES 15–25

About medium size for genus, narrowly elliptical in outline, length slightly greater than width; hinge narrower than midwidth; anterior broadly rounded; anterior and lateral profiles moderately convex; interarea short and wide; delthyrium narrow, thin pseudodeltidium in holotype. Cicatrix small. Surface marked by numerous, short, slender spines; stouter and longer spines along posterior margin. Brachial valve varying from nearly smooth to pitted.

Pedicle valve interior with large teeth; muscle area only slightly thickened. Brachial valve interior

with small cardinal process and low slender median septum.

MEASUREMENTS (in mm).—From locality USNM 731 specimens 152634b (holotype) and d, respectively: length 10.6, (?); brachial valve length 10.0, 7.6; width 13.0, 9.0; hinge width 11.0, 9.5; height 3.6, (?).

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler Member).

LOCALITY.—USNM 731.

DIAGNOSIS.—Medium-sized *Heteralosia* with numerous fine spines on the exterior of the pedicle valve.

TYPES.—Holotype: USNM 152634b. Figured paratypes: USNM 152634a, c, d.

COMPARISON.—This differs from the other species herein described by its finely spinose exterior. It is a rare species only known from one locality.

*Heteralosia vidriensis*, new species

PLATE 192: FIGURES 1–10; PLATE 193: FIGURES 28–44

About medium size for genus, transversely quadrangular in outline, width greater than length; cardinal extremities nearly rectangular, slightly obtuse or slightly acute; sides gently rounded; anterior broadly rounded. Attachment surface usually small, interarea short, wide; rhizoid spines slightly more than 2 mm long and slender, tapering, scattered openly on surface. Ornament spines concentrated on ears, slender, and also scattered over whole surface.

Pedicle valve moderately convex in lateral profile, maximum convexity at about midvalve. Anterior profile broadly domed with fairly short slopes moderately steep. Median region generally fairly strongly swollen, swelling extending to anterior in some specimens.

Brachial valve moderately convex, fairly well-fitting concavity of pedicle valve; hinge wide, extremities slightly concave. Anterior and sides moderately deflected in dorsad direction. Surface closely and fairly deeply pitted to match spines of opposite valve.

Pedicle valve interior with small narrow delthyrium covered by narrowly arched pseudodeltidium; teeth small with flat dorsad surface; adductor platform short but strongly developed in adults.

Brachial valve with short, low cardinal process with median depression on shaft; median ridge con-



tinuous and reaching anterior to midvalve; sockets small.

MEASUREMENTS. (in mm).—

	length	brach- ial valve length	width	hinge width	height
USNM 721u					
152632a	8.2	?	10.7	9.6	3.9
152632b	?	6.6	11.6	10.0	?
152632c	9.6	?	12.0	11.6	3.9
152632d	10.4	?	13.8	10.0	5.1
152632e	9.6	?	14.0	12.9	3.1
152632g (holotype)	9.4	?	12.2	11.7	3.7

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation, Road Canyon Formation.

LOCALITIES.—Cathedral Mountain: USNM 721u. Road Canyon: USNM 722e.

DIAGNOSIS.—Medium-sized *Heteralosia* with transversely rectangular outline and short, slender ornament spines.

TYPES.—Holotype: USNM 152632g. Figured paratypes: USNM 152632a, c, d, f, h. Measured paratypes: USNM 152632a–d, e. Unfigured paratypes: USNM 152632e.

COMPARISON.—The transversely rectangular outline and moderate convexity of the pedicle valve distinguish this species from *H. hystricula* (Girty). The same features may be used to distinguish it from *H. magnispina*, new species, but, in addition, the short, slender spines make separation of the two easy.

DISCUSSION.—This is a rare species and only 17 specimens were taken. Brachial valves are rare, consequently the variation of the brachial structures cannot be detailed. An interesting feature of this species is the scattered ornament spines over the body of the shell. This may be a consequence of its low convexity and the fact that the cicatrix is small. Variation of the pedicle valves is shown by rounding of the cardinal extremities, narrowing of some of the specimens, and differences in depth.

### *Heteralosia* species 1

PLATE 193: FIGURES 1, 2

A possible new species is represented by a single specimen which is nearly circular in outline, deeply concave dorsally, and has a correspondingly strongly

convex pedicle valve. The hinge is much narrower than the maximum width which is at midvalve. The surface of the pedicle valve is provided with numerous fine, prostrate spines, and the brachial valve is nearly smooth, not dimpled as is common in the genus. Measurements in mm are: length 11.3, brachial valve length 8.7, hinge width 5.9, greatest width 12.0, thickness 3.5, and height 6.4.

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITY.—USNM 702.

TYPE.—Figured and described specimen 152631.

COMPARISON.—This specimen resembles *H. hystricula* (Girty) but some differences are apparent when the measurements of the latter are compared. The Cathedral Mountain specimen is deeper and more convex than the common Word specimens. Furthermore, the prostrate spines of *Heteralosia* species 1 appear to be finer and more numerous than those of *H. hystricula*. These differences indicate a species quite different from *H. hystricula*. Inasmuch as a single specimen is all that is known, the species has not been named.

### *Heteralosia* species 2

PLATE 193: FIGURE 14

The only specimen representing this species may be a young one or it may represent a flat and thin-bodied form such as *H. mexicana* Cooper. The specimen measures 5.7 mm in length by 7.1 mm in width and is about one mm thick. The cicatrix is small, suggesting that the specimen may be an adult flat species. Spines on the pedicle valve are few and distantly scattered.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITY.—USNM 707e.

TYPE.—Figured and described specimen USNM 154120.

DISCUSSION.—No other species except the Mexican one referred to above is like this Road Canyon specimen.

### *Heteralosia* species 3

This is the largest *Heteralosia* so far found in the Permian of West Texas. It is 17 mm long by 18 mm wide. It is strongly convex in both profiles and

it has short, slender, body spines but its ornament spines are thick and stout and concentrated on the ears and sides as well as scattered over the body. The single pedicle valve is from Road Canyon Formation at USNM 721y.

Described specimen USNM 152633.

#### *Heteralosia* species 4

PLATE 193: FIGURE 9

This is a small species with a strongly bulbous pedicle valve which is 9 mm. long by 11 mm. wide. The lateral and anterior slopes are very steep, the spines slender, strongly oblique but not prone and well-scattered. Bone Spring Formation: AMNH 628.

Described specimen USNM 151293a.

#### *Heteralosia* species 5

A coarse-spined species with length and width nearly equal occurs at USNM 721u, Cathedral Mountain Formation.

Described specimen USNM 152635.

#### *Heteralosia* species 6

PLATE 193: FIGURE 10

A moderately fine-spined species reminiscent of *H. hystricula* but not so convex and with somewhat fewer spines. Bell Canyon Formation, Rader Member. AMNH 410.

Figured specimen USNM 152636.

#### *Heteralosia* species 7

PLATE 193: FIGURES 3-8, 11

About medium size for genus, transversely rectangular in outline, sides gently rounded, subtruncated anterior margin producing narrowly rounded anterolateral extremities. Interarea very short. Surface with short, moderately fine, prone, ornament spines; halteroid spines stout, few, scattered.

Pedicle valve gently convex in anterior and lateral profile; median region with slight sulcus. Teeth small; muscle region not thickened but with incipient platform. Brachial valve flatly concave; cardinal process short, narrowly pointed. Median septum low, continuous.

MEASUREMENTS (in mm).—From locality USNM 728f, specimens 151274a and 151270, respectively: length 8.3, 7.6; brachial valves unmeasurable; width 11.0, 9.8; hinge width 10.6, 9.6; height 3.5, 2.7.

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation; Bone Spring Formation.

LOCALITIES.—Skinner Ranch: USNM 722-1. Bone Spring: USNM 728f.

DIAGNOSIS.—Rectangular *Heteralosia* of medium size, low convexity, and fine spines.

TYPES.—Figured specimens: USNM 151274a-c. Described specimen: USNM 151270.

COMPARISON.—This species suggests *H. vidriensis*, new species, but differs in its less convex profile, squarer outline, and sulcate anterior.

### Subfamily CTENALOSIINAE Muir-Wood and Cooper, 1960

Strophalosiidae with numerous small teeth and sockets along the hinge of both valves; obscurely costate anteriorly, brachial valve and pedicle valve rugose, with no spines.

Genus: *Ctenalosia* Cooper and Stehli, 1955.

Since its description the range of this interesting genus has been extended both geographically and stratigraphically. It is now known from the Bell Canyon Formation and the China Tank and Appel Ranch members of the Word Formation as well as the Getaway Member of the Cherry Canyon Formation where it is common. An unusually large species has been taken from the Park City Formation in Wyoming. A primitive member occurs in the Neal Ranch Formation.

#### Genus *Ctenalosia* Cooper and Stehli, 1955

*Ctenalosia* Cooper and Stehli, 1955:470.—Muir-Wood and Cooper, 1960:91.

Small Strophalosiacea attached by most of ventral surface; usually wider than long and plano-convex to slightly biconvex; hinge usually narrower than midwidth; anterior commissure with moderate dorsal fold. Spines commonly of rhizoid type but rarely ornamental, located on cardinal extremities and umbonal slopes. Anterior unattached part of pedicle valve marked by subdued costellae. Brachial valve marked by concentric undulations and obscure radial costellae.

Pedicle valve somewhat saucer-shaped but with anterior part strongly deflected in dorsal direction; interarea moderately long, pseudodeltidium flat. Brachial valve operculiform, with short interarea.

Pedicle valve interior with hinge-line denticulate, teeth small and protruding; myophragm prominent, dividing somewhat heart-shaped elevated adductor platform; diductor scars flabellate.

Brachial valve with hinge margin marked by row of deep pits or sockets for teeth of pedicle valve under short interarea; cardinal process small and narrow, at right angles to valve surface or at oblique angle; shaft moderately long, indented medially by groove; myophore with wide median lobe but lateral lobes reduced and laterally compressed, adductor field small, usually deeply impressed and commonly excavated anteriorly; brevisseptum short; brachial ridges large, occupying most of lateral areas; median groove margined by elevated inner walls of brachial ridges.

TYPE-SPECIES.—*Ctenalosia fixata* Cooper and Stehli (1955:471, pl. 52, A: figs. 1–16).

DISCUSSION.—*Ctenalosia* is a genus of small brachiopods having the general aspect of *Heteralosia*. Except for small external differences the two are readily confused. *Heteralosia* is the only Permian genus with which *Ctenalosia* is likely to be mistaken and the two occur together at several localities. Externally the two genera may be distinguished by the fact that *Ctenalosia* has no ornament spines whereas those of *Heteralosia* are prominent. Furthermore, the anterior surface of *Ctenalosia* is commonly costellate but that of *Heteralosia* is usually without costellae. The major differences are on the inside of the two genera. *Ctenalosia* is readily recognized by the posterior margin of either valve; the pedicle valve has a row of teeth and the brachial valve a row of sockets. *Heteralosia* has no articulation other than the normal pair of teeth and sockets with which most Strophalosiaceae are provided. Another distinguishing feature of *Ctenalosia* is the prominent anterior fold and sulcus, not developed in *Heteralosia*. Several details of the anatomy of *Ctenalosia* may be advantageously discussed.

In specimens favorably preserved, especially those growing on a flat surface, the pedicle valve palintrope is well developed. It is fairly long and flat, the pseudodeltidium scarcely disturbing the even surface. The delthyrium is moderately large, but is

usually covered almost completely by the flat pseudodeltidium. In some specimens the pseudodeltidium is marked by a narrow smooth area at about its center, but generally its outline is difficult to determine.

Generally the sides of the delthyrium of *Ctenalosia* are not marked by a tooth at each anterior angle as in other Strophalosiaceae. Each is rather marked by a row of irregular teeth, the largest of which may appear at almost any point along the hinge line. The teeth are irregular, triangular, generally pointed projections lying in the tissue that supports the palintrope. Thus they jut out just under (anterior to) the edge of the palintrope. In some instances the smaller teeth are near midvalve bounding the delthyrium but in others smaller teeth are scattered in the row. Two or more teeth may grow together to form a single large tooth; in other places, where a tooth has failed to develop, a gap may appear in the row. In some, the teeth are closely crowded, in others, widely separated; the two conditions depending on factors of growth, crowding, and age.

The adductor platform of the pedicle valve is variable, as are all other features of this genus. In the young, the myophragm appears as a low, rounded ridge with faint thickenings. The myophragm maintains its prominence in all growth stages and no specimen was seen in which it had been engulfed. In old age the muscle platform in some specimens is excavated anteriorly so that it hangs over the median part of the valve, the myophragm becoming exaggerated and projecting vertically as a real septum.

The sockets in the brachial valve are as irregular in size as the teeth. Like the teeth, they are located in the secondary tissue just under (anterior to) the palintrope. In perfectly preserved specimens the sockets underlie the palintrope, but in many specimens the palintrope has been stripped away and the sockets appear as a serrated margin, the walls between the sockets standing up as ridges.

In the young of *Ctenalosia* the cardinal process is narrowly compressed and the myophore is no wider than the shaft. The anteroventral surface of the shaft is marked by a deep groove which divides the shaft longitudinally into two equal rounded bars. The groove terminates near the distal end of the cardinal process, where the myophore is somewhat flattened. Anteriorly the groove con-



tinues the full length of the shaft and onto the valve floor, where it separates two low rounded ridges. These extend anteriorly between the adductor scars but diverge laterally at the anterior end of the scars and form an anterior bounding ridge to the adductor field in many specimens.

The myophore of young specimens is narrowly compressed, but the median lobe is the widest of the three. The lateral lobes are tightly pressed against the median one, and the groove between is narrow. In some valves the lateral lobes overlap the median lobe. With age many specimens widen the myophore, and in a few specimens it becomes definitely trilobed, but the median lobe always retains its greater width.

In young specimens the cardinal process is usually at right angles to the valve floor, but with growth it becomes more erect relative to the floor; however, no specimens were seen where it had reached the perpendicular when the valve is viewed from the ventral side.

The development of the cardinal process of this genus is as variable as that of all other attached productids, and the same patterns are discernible. Many specimens that had not yet attained full adult length and width nevertheless exhibit full adult interior characters. The adductor scars are deeply sunk and are surrounded by thickened rims. The myophore is thickened and expanded, and the brachial ridges are greatly exaggerated. On the other hand some of the largest brachial valves in the collection have a small underdeveloped cardinal process with a deep median groove, scarcely defined adductor scars, and only faintly developed brachial ridges. No basis for specific distinction could be discovered in these specimens; consequently, it is concluded that the variations are induced by the accidents of living conditions favorable to some individuals, less so to others.

The adductor field is as variable as the cardinal process. Usually the scars are deeply sunk in the tissue of the floor and consist of an anterior and posterior pair as usual. In some, even large shells, the scars are scarcely visible but this is unusual. It is commoner for them to be deeply sunk, and in well-nourished specimens they are defined by the ridges mentioned above. In a few, these ridges are excavated somewhat on the anterior side, and the adductor field then has the appearance of an elevated platform.

The brachial ridge is another variously developed feature of the brachial valve interior, from invisible in some large specimens to so strongly developed that they form elevated ridges. In the ideally developed specimen the ridge originates on each side of the adductor field at the point where the anterior and posterior adductors meet. The ridge then swings anterolaterally and roughly parallel to the lateral margin to make a narrow loop posteriorly at the edge of the sulcus (fold of the exterior), and then dying out just anterior to mid-valve. In some specimens the strongest parts of the brachial loop are the part parallel to the antero-lateral margin and that bounding the sulcus. The latter part is so strong and elevated in some that it lends considerable depth to the sulcus.

The median sulcus as in most productids is not very deep. In *Ctenalosia* it is short, shallow and wide, commonly defined by the inner ridge of the brachial ridge. Externally the sulcus appears as a low fold, frequently not clearly discernible except for the emargination of the pedicle valve, in which a moderately deep sulcus is produced to match the dorsal fold.

The growth of *Ctenalosia* is like that described for *Heteralosia* and other closely attached genera. Usually specimens that attach to broad, flat surfaces are likewise broad, with well-developed interareas and wide hinges. On the other hand specimens that attach to bryozoans, crinoid stems, or other round objects are generally narrow-hinged and have long interareas. Furthermore, rhizoid spine development is more scattered, the spines longer, and in many instances, stouter. The holotype of the type species is an example of a specimen attached to a narrowly rounded object. The rhizoid spines are scattered over most of the exterior of the pedicle valve. In one unusual specimen the posterior part of the pedicle valve and its anchor spines form a solid ring. Usually however, the cicatrix is broad, and the rhizoid spines form a fringe around it.

A feature observed in a number of pedicle valves from USNM 728 may be due to burrowing organisms or may result from ingrowing spines. These are long tubes that generally extend from about the anterior end of the adductor field to a short distance from the anterior margins. The tubes are generally straight; commonly they are fairly deeply buried near their origin, but emerge on the inner

valve surface and extend along it roughly parallel to other spines. The exterior part of the spines is usually thin-walled and the apertures round. These suggest rhizoid spines that were engulfed by the growing shell and continued to flourish for some time as described in *Waagenoconcha* (Grant, 1966a, b). Perhaps, however, they represent other organisms that lived under the mantle of the brachiopod. In the latter case, irritation caused by the intruder would lead to the expectation that the brachiopod would have thickened the shell at these places and attempted to seal off or smother the "parasite."

Ctenalosauria fixata Cooper and Stehli

PLATE 197: FIGURES 1-65

Ctenalosauria fixata Cooper and Stehli, 1955:471, pl. 52A: figs. 1-16.—Muir-Wood and Cooper, 1960:91, pl. 31: figs. 17-25.

Small, attached shells forming shallow to deep saucer; outline variable, wider than long or vice versa depending on substrate; hinge usually narrower than midwidth; sides rounded; anterior margin rounded to emarginate depending on age. Attached by umbo and anchored by ring of stout rhizoid spines. Surface of pedicle valve obscurely to moderately strongly costellate. Exterior of brachial valve without spines, wrinkled concentrically or with obscure costellae; infrequently with pattern of host impressed on exterior.

Pedicle valve with most of umbonal surface occupied by cicatrix in many specimens, thus forming shallow or deep saucer more elevated on anterior side than on posterior. Some specimens attached to round objects, productellid in outline, with strong and fairly even convexity in lateral profile, but with domed anterior profile. Anterior slope long and steep. Interarea moderately long, flat. Cardinal extremities reduced, usually partaking in fixation. Sulcus shallow but indenting front margin.

Brachial valve variable, generally gently convex in lateral profile and broadly convex in anterior profile, but many specimens broadly concave in both profiles. Ears small and flattened, well defined but not prominent. Margin thickened and slightly deflected in dorsal direction. Fold low, externally not clearly defined in most specimens but deep and pronounced as sulcus internally.

Interior of both valves as defined for genus.  
MEASUREMENTS (in mm).—

		<i>brach- ial valve length</i>	<i>maxi- mum width</i>	<i>hinge width</i>	<i>height</i>	<i>thick- ness</i>
USNM 706c						
124123a	7.0	6.3	8.1	4.7	3.2	2.7
(holotype)						
124123b	6.9	4.5	7.0	4.3	3.0	2.4
124123d	6.2	?	9.4	6.3	4.2?	?
152642a	9.0	?	9.8	8.1	5.2	?
152642b	6.4	4.8	8.0	6.4	3.8?	3.0
USNM 728						
152643a	6.6	?	8.9	6.6	2.8	?
152643b	7.4	5.8	8.7	5.0	5.0	4.2
152643c	6.1	4.8	8.3	5.2	2.8	2.4

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member), Word Formation (China Tank, Willis Ranch, and Appel Ranch members and lenses between the last two), Bell Canyon Formation (Hegler and McCombs members).

LOCALITIES.—China Tank: USNM 706c. Lens: AMNH 512, 652; USNM 706b. Getaway: USNM 728. Appel Ranch: USNM 706d, 714o, 715i, 719z, 722t, 727j. Hegler: USNM 732a. McCombs: AMNH 409.

TYPES.—Holotype: USNM 124123a. Figured paratypes: USNM 124123b-i; 124161a. Measured paratypes: USNM 124123b, d. Measured hypotypes: USNM 152642a, b; 152643a-c. Unfigured paratypes: USNM 124123j, 124161b. Figured hypotypes: USNM 152642a, b; 154123; 154124a, b; 154125a-c; 154126a-c; 154127a-c; 154128a-k.

DISCUSSION.—Some important differences between the specimens from the Glass Mountains and those of the Guadalupe Mountains are evident. Specimens from the latter are generally more robust, with thicker shells and more positive structures in the interior. The Glass Mountains specimens are generally thin-shelled and the interior features are not as prominent as in most of the Guadalupe specimens. Nevertheless, the variation is so great in the specimens from both regions that some from the Guadalupe Mountains have the same delicate nature as those from the Glass Mountains. Some specimens from the Glass Mountains exhibit greatly thickened structures, such as the myophore of the cardinal process and the brachial ridges; however, the majority of specimens from that region are more

delicately constructed than those from the Guadalupe Mountains. It is suggested that an ecological factor was operating in the two regions because no basis for separating species could be found on the exterior.

This species is known only from the Getaway Member in the Guadalupe Mountains and is common at only one spot. At USNM 728 (=AMNH 512) it occurs in a sponge bioherm where it found congenial conditions and ample surface to fix itself on the solid sponges. In the Glass Mountains *Ctenalosis* is usually fixed to other shells rather than to sponges. Furthermore, the bottom was a fine sandy lime mud in each of the Word limestone members. Generally, the fossil occurrences in these Word limestones represent thanatocoenose assemblages of dead shells washed together. *Ctenalosis* has an odd distribution in these limestones; it is rare in the China Tank Member, but only a single specimen has been found in the Willis Ranch Member. Inasmuch as several tons of limestone from this part of the Word Formation were dissolved in the course of this study, the species is thus extremely rare in that member. A fair number of specimens was taken from a lesser bulk of Word limestone (Appel Ranch Member). It is thus commoner in this member but is, nevertheless, a rare shell.

### *Ctenalosis primitiva*, new species

PLATE 192: FIGURES 26-34

Small, strongly convex with small cicatrix of attachment; sides and anterior rounded; free surface costellate; anchor spines stout, but ornament spines long and slender. Interarea short. Brachial valve moderately concave, with maximum concavity toward anterior. Surface of brachial valve wrinkled, pitted, margin of larger specimens costellated to correspond to pedicle valve.

Pedicle valve interior with few, poorly developed comblike teeth as well as normal teeth. Brachial valve interior with irregular sockets; cardinal process widely trilobed, shaft short. Sockets poorly defined. Septum low, highest anteriorly and reaching just beyond midvalve. Adductor field fairly wide.

MEASUREMENTS (in mm).—From locality USNM

701, specimens 151249a (holotype) and b (paratype), respectively: length 5.2, 4.8; brachial valve length 4.7, 4.1; width 6.6, 5.5; hinge width 5.3, 3.2; thickness 2.4, 2.7; height 3.0, 3.8.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation.

LOCALITIES.—USNM 701, 701d, 721g.

DIAGNOSIS.—Small *Ctenalosis* with incipiently denticulate hinge and ornament spines.

TYPES.—Holotype: USNM 151249a. Figured paratypes: USNM 151249c, d; 151267. Measured paratype: USNM 151249b. Unfigured paratype: USNM 151249b.

COMPARISON.—Small size and the strongly costellate anterior free part of the pedicle valve, together with the incipient nature of the comblike teeth along the hinge, separate this species from other described forms. Furthermore, the interior of the brachial valve is rather heteralosiid without the median sulcus and without strong median ridges.

DISCUSSION.—This species is of great interest because it combines characters of *Heteralosis* and *Ctenalosis*. The exterior surface of the free part of the valve is costellate like that of *Ctenalosis*, but has ornament spines like those of *Heteralosis*. The interior of the brachial valve is like that of *Heteralosis*. Missing inside the brachial valve are the strong adductor pits and the brachial ridges. The shaft of the cardinal process is not so long and is not connected to the brevisseptum. This species probably represents an ancestral stage in the development of *Ctenalosis*.

### *Ctenalosis rotunda*, new species

PLATE 192: FIGURES 20-25, 35-45

Small, with thick shell, subcircular in outline with well-rounded sides and anterior margin. Height not great; anterior exposed surface fairly strongly costellate. Hinge narrower than maximum width, at midvalve. Attachment surface variable but fairly large; interarea short. Teeth of pedicle valve large and few; sockets of brachial valve deep. Brachial valve unevenly convex and with anterior depression parallel to margin in anterior part. Interior with large and ponderous cardinal process, short brevisseptum, and large, elevated adductor platforms.

## MEASUREMENTS (in mm).—

	length	brach- ial valve length	width	hinge width	height	thick- ness
AMNH 635						
152645c	7.0	5.8	6.3	4.7	2.9	3.4
(holotype)						
152645a	4.5	4.0	5.2	2.7	2.9	
152645b	3.9	3.6	4.9	2.4	3.1	3.3

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler Member).

LOCALITIES.—AMNH 635, USNM 732a.

DIAGNOSIS.—Small, thick-shelled *Ctenalosis* with round outline and a few large teeth.

TYPES.—Holotype: USNM 152645c. Figured paratypes: USNM 152645b; 154121a, b. Measured paratypes: USNM 152645a, b.

COMPARISON.—The three specimens available indicate a species smaller and thicker-shelled than *C. fixata*, with coarser teeth in the pedicle valve and larger, more elevated adductor platforms.

*Ctenalosis transversa*, new species

PLATE 198: FIGURES 1–19

Large for genus, wider than long and broadly elliptical in outline; sides narrowly rounded; anterior margin broadly rounded; pedicle valve attached by at least half its length. Free surfaces of pedicle valve marked by strong costae, about 7 in 5 mm at front margin; brachial valves generally with visceral disc region irregularly marked by rounded humps or interrupted costae; anterior margin with well-marked costae.

Pedicle valve strongly geniculated, visceral disc region attached to hard surface, anterior trail portion free and extending at right angle or slightly obtuse angle from surface of attachment; anterior commissure marked by strong sulcus best shown at margin. Rhizoid spines forming ring around attached part; body or ornament spines long and arising at low angle, few and scattered. Interarea moderately long.

Brachial valve unevenly concave, visceral disc region usually slightly convex, trail geniculated at low angle, bent in dorsal direction. Anterior margin with broad fold.

Pedicle valve interior with short median ridge and

moderately elevated, anteriorly thickened muscle platform. Teeth along cardinal margin long, protruding.

Brachial valve interior with variable but long erect cardinal process having trilobed myophore. Cardinal process shaft usually indented. Median septum strong. Adductor platform thickened, anteriorly free of valve floor. Sockets deep and prominent.

## MEASUREMENTS (in mm).—

	length	brach- ial valve length	mid- width	hinge width	height	thick- ness
USNM 762						
152644a	8.5	?	11.7	7.7	2.4?	?
152644b	9.4	?	12.7	6.9	3.0?	?
152644c	8.2	?	11.3	7.9	1.3?	?
152644d	9.9	7.6	12.5	7.3	2.3	1.1?
(holotype)						

STRATIGRAPHIC OCCURRENCE.—Park City Formation (Franson Member).

LOCALITIES.—USNM 760, 762.

DIAGNOSIS.—Large, strongly costate *Ctenalosis* with long trail.

TYPES.—Holotype: USNM 152644d. Figured paratypes: USNM 152644a, c, e, g, h; 154134a-c. Measured paratypes: USNM 152644a-c. Unfigured paratypes: USNM 152644b, f.

COMPARISON.—*Ctenalosis fixata* Cooper and Stehli is the only species to which this one can be compared. It is a much larger and more strongly ornamented species than the Glass Mountains and Guadalupe Mountains form. A stouter cardinal process and more thickening of the interior of both valves characterizes *C. fixata* but the brachial valve adductor platform is not as free at the anterior end as it is in *C. transversa*. Furthermore, the thickening of the muscle platform in the pedicle valve of *C. transversa* is not so strong as that of *C. fixata*.

DISCUSSION.—The early stages of this species are low and slightly convex, the pedicle valve spreads gradually over the surface of attachment until it attains a length of 5 mm. or more, provided the substratum will permit. Growth then takes place at an angle to the subsurface. This angle may be initially more than a right angle, but as growth continues, the anterior curves sufficiently for the trail to approximate a right angle from the attachment surface. Anchoring in the early stage is by



cementation and strengthening with rhizoid spines which form a ring around the young *Ctenalosia*. After the trail is well developed, body spines, arising at a low angle to the trail surface, curve anterodorsally and undoubtedly hung over the aperture.

The folding of this shell, as in *C. fixata*, is variable but is one of its distinctive features. This generally originates as a slight wave of the anterior margin toward the dorsal valve but it deepens as the margin grows away from the surface of attachment. In occasional specimens it may become so strong as to create an elongate tongue on the pedicle valve.

The most interesting structure of the interior of the pedicle valve is the teeth, which are generally long and slender but develop interesting aberrations. Usually the tooth is fanglike, slightly curved toward the posterior, fairly sharply pointed, and about .25 mm in length, but, in rare shells attains a length of 1 mm. When viewed from beneath the palintrope, the teeth in some specimens form distinct ridges; in others they have been covered by shell substance and only the articulating or free parts are visible.

Several specimens show interesting aberrations in which teeth have been coalesced by shell material just beneath the palintrope edge to form an irregular plate or extra socket. In another, these secondary structures form a second set of irregularly shaped teeth under the primary set.

The development of the myophragm, the small plate on the adductor platform, is as variable as the development of the platform itself. In some specimens it is strong and approximates a septum, but in others it seems not to have formed. This seems not to be a matter of preservation or poor silicification, because no trace of the structure is to be seen in these shells. Although the platform varies from scarcely perceptible to widely triangular and strongly elevated, no specimens were seen in which the adductor platform is anteriorly excavated.

The interarea of this species is fairly long and is completely flat; the pseudodeltidium is flush with the sides of the interarea, and itself flat and difficult to differentiate. Usually it is thin and is commonly crushed out to form a gap. When uncrushed, its position is clear by a gap in the battery of teeth.

Most specimens of the brachial valve show the posterior as a row of pegs with spaces between them.

These specimens are imperfect. In perfect condition the sockets appear as a horizontal row of deep pits just anterior to the posterior margin. Usually however, the posterior margin is eroded away, leaving the space between the sockets as pits. It is also common for the posterior dorsal surface to be so worn that the sockets appear as holes through the posterior of the valve.

The cardinal process is long-shafted and slender or stout. In young specimens it usually extends at a right angle to the valve directly into the body cavity, but in older specimens it rotates to stand at about 45° to the valve surface. The anterior part of the shaft in young specimens is excavated, but in older forms it may be completely solid or may retain the elongated excavation.

The myophore is notable for the large size of its median lobe. This is usually wider and longer than the lateral lobes and protrudes beyond the lateral lobes. In some specimens the lateral lobes are closely pressed to the median lobes but in others they are more flaring which emphasizes the trilobation.

The adductor platform is strongly excavated anteriorly, the lobes to which the anterior adductor pair are attached hanging free in the valve. The posterior scars are located somewhat outside and behind the anterior scars and are generally not thickened, as they are attached to the valve floor. The degree of anterior excavation is variable, but is noticeable in all specimens and extreme in some.

The brevisseptum is strongly developed anteriorly, but is usually buried at its proximal end in the tissue of the adductor platform. Brachial ridges are only indistinctly developed in this species.

*Ctenalosia transversa* most commonly occurs attached to the brachial valve of *Bathymyonia*, but has been seen adhering to *Xestotrema pulchrum* and *Derbyia*. It also clings rarely to bryozoa.

#### Family TEGULIFERINIDAE Muir-Wood and Cooper, 1960

Strophalosiiacea having an obliquely conical pedicle valve attached by its apex and anchored by rhizoid spines; pseudodeltidium and interareas absent; brachial valve opercular; cardinal process long-shafted, bilobate, no alveolus. Little or no development of apical cystose shell.

Genera in West Texas: *Teguliferina* Schuchert and LeVene (1929), *Acritosia* Cooper and Grant (1969).

This family appears in the Pennsylvanian but becomes abundant in the Neal Ranch Formation, where there are small patch reefs or bioherms of them. It is represented by *Acritosia* in the Skinner Ranch Formation, but the family does not range higher than the Skinner Ranch except for *A. vestibula*, new species, from the Road Canyon, tentatively referred to that genus.

### Genus *Teguliferina* Schuchert and LeVene, 1929

*Tegulifera* Schellwien (not Saalmüller, 1880, insect), 1898: 362; 1900b:59.

*Teguliferina* Schuchert and LeVene, 1929:121.—Stehli, 1954: 330.—Muir-Wood and Cooper, 1960:92.

*Planispina* Stehli, 1954:331.—Muir-Wood and Cooper, 1960: 94.

Small to medium, forming low oblique cones or (in later species) rounded cones with eccentric apex. Brachial valve opercular and usually lying deeply within cone, to form a vestibule, at a steep angle to the vertical. Exterior surface usually with strong growth lines or ragged concentric lamellae representing resting stages in growth; surface usually with fine concentric growth lines and, in some species, obscure radial lines. Shell attached by apex and anchored by smooth, round spines in young stages, but commonly joined by flattened webs between them or with broad flattened spines and sheetlike expansions. Inside of anterior margin of pedicle valve provided with stout protective spines on ventral side partially or almost wholly covering opening.

Pedicle valve with very narrow, straight hinge and short triangular interarea commonly covered by shell layers. Sockets for articulation of brachial valve lying at anterolateral extremities of hinge usually narrow and deep; aulacotermia strong and forming prominent ridge around valve interior. Muscle area small, with anterior median callosity divided by septum commonly forked anteriorly; adductor scars elongate; diductor impressions subflabellate; interior spine extensions common, especially on sides.

Brachial valve pyriform in outline, narrow hinge having narrow ginglymus (?); articulating processes

forming narrow, rounded projections at hinge extremities; lateral ridges strong, forming marginal thickening; cardinal process long-shafted, with narrow or slightly expanded trilobed myophore; median ridge supporting cardinal process and extending to middle of adductor field; brevisseptum short, extending anterior to midvalve, in some species uniting with median ridge to form long continuous ridge. Adductor scars elongate. Brachial ridges indistinct.

TYPE-SPECIES.—*Tegulifera deformis* Schellwien (1898:362).

DIAGNOSIS.—Small, obliquely conical Teguliferinidae having weblike, flat expansions between the rhizoid spines.

COMPARISON.—The peculiar weblike expansions between the rhizoid spines of this genus separate it from all others of the family. It differs from *Acritosia* in its generally smaller size and strictly apical position of the articulation. It is easily distinguished from *Taphrosestria* by the squat form of that genus and the fact that anastomosing spines cover the entire aperture of *Taphrosestria*.

Stehli (1954:331) created the genus *Planispina* for conical shells having the internal and external features of *Teguliferina*, and, in addition, flat webs between the rhizoid spines. He regarded the teguliferinids with rhizoid spines having a round cross section as the true *Teguliferina*. He had apparently no specimens of the European species and consequently was not aware of the flattened rhizoid spines and webs. These features are visible on a number of specimens of unsilicified teguliferinas from the Pennsylvanian of Texas, Kansas, Illinois, and Oklahoma, as well as on European specimens. The feature seems to be characteristic of *Teguliferina* and thus *Planispina* becomes a subjective junior synonym of *Teguliferina*.

DISCUSSION.—*Teguliferina* is one of the commonest inhabitants of the Wolfcampian and late Pennsylvanian bioherms. In some of them it occurs in such numbers that it makes up most of the biohermal structure. Such masses give an excellent opportunity to study the clusters as well as the individual. The clusters are composed of young and old specimens thus making it possible to remark on the ontogeny of the various species.

The mode of growth is one of the distinguishing characters of *Teguliferina*. The junction point of the two valves remains apical throughout the life

of the animal, although the form of the cup radically changes from an oblique to a nearly vertical cone. The posterior side thus develops a long hood that envelopes the hinge region. This hood is internally strongly papillose and must have been covered by an extension of the mantle. In *Teguliferina* no protective spines have been observed on the posterior side to protect or cover the hinge region. On the anterior side, however, the cup is well protected by stout spines, usually variable within a single species. In many individuals these spines merely form a ring around the anterior side. They commonly project nearly vertically or at a moderate angle to the exterior surface. In others they are massive and stout and nearly cover or completely cross the opening of the vestibule. The spines are commonly single but many of them bifurcate, while others may join at some distance from the margin. These protective spines are so variable in many species that they do not afford a reliable specific character.

The young *Teguliferina* reach a fair size before the oblique cone starts to equalize its anterior and posterior sides. In the young specimens the anterior side is strongly elevated and has a rim of protective spines inside the anterior rim. A hood starts to form over the hinge region and this, once started, grows rapidly to equalize the two sides of the cone. When the hood is fully grown it attains the same height as the posterior side. The hood is usually strongly papillose on its inner surface, the papillae approximating stubby spines in some specimens.

A cone-in-cone effect results from a series of apertures arising one within another probably by contraction and expansion of the mantle in the upward growth of the animal. Some specimens show this effect very strongly, and have a very ragged appearance as a consequence of it.

The cone is anchored by spines which, in the young, are round and delicate. As the cup continues its growth and need for more solid anchoring arises, the spines are further reinforced by development of webs between them and external sheets of shell substance that may also serve as an anchoring medium. This material originates as a spine, starting as a spine opening and expanding anteriorly and laterally and frequently branching in its growth. The sheets commonly wrap around or partially envelope spines already formed. It is as though a thick viscous liquid was squeezed out of a narrow

opening and expanded over all irregularities in its way. The sheetlike substance appears to be connected with the external layer and is concentrically marked similar to the exterior of the cup. The development of the webs is not uniform among the species; in *T. boesei* they appear at about the time the posterior hood begins to develop, after the individual had been long attached by normal round spines. In the Gaptank species the webs appear at a very early stage, and no round spines were seen.

The most interesting features of the pedicle valve are those of the hinge region which is unlike the normal brachiopod because the sockets of articulation are located in this valve. The inner cavity of the pedicle valve is pear-shaped, narrowing posteriorly. At the narrowed end are the two small shelflike plates (or palintrope) separated by a triangular opening into which the lophidium of the cardinal process is inserted. The anterior edges of the shelflike plates are the hinge edge and terminate laterally against the valve wall. The sockets for the insertion of the articulating process are located at the anterolateral edge of the triangular plates. The surface of the palintrope constitutes an interarea like that of normal brachiopods. A few exfoliated specimens show this interarea as a small triangular surface at the beak and with a small cover or elytridium over the posterior part of the triangular opening. Thus this structure, except for the sockets which are aberrant, is like that of the Strophalosiidae or Aulostegidae.

The palintrope is supported by shell thickening that forms a ridge on each side of the narrowed posterior part of the valve and extends anterolaterally around the entire inside of the cup. This ridge is the aulacotermia. It is thickest posteriorly and in some specimens is longitudinally divided for some distance. This shelf forms the resting place of the sides of the brachial valve.

At the posterior, narrowed end of the pedicle valve, opposite the curve forming the narrowing, is located a pit of variable dimensions, the surface of which is smooth or papillose. In some specimens this pit appears to be completely absent; in others it is a conspicuous feature. Its presence or absence appears to have no significance in the formation of species. A similar feature appears in richthofeniids.

The muscle scars of the pedicle valve are not generally strongly impressed. The muscle field occupies the narrowed end of the cup and is usually some-

what thickened especially at the anterior. A median myophragm is generally present which forks narrowly at the anterior end. The adductors are elongate and the diductors subflabellate.

A feature common in productaceans, and also in richthofeniids, is the presence of spine bases on the interior of the cup. These are fairly common, especially on the lateral walls of many specimens. In the younger individuals these appear as small holes, but in older and larger forms they have distinct rims around them.

The brachial valve is also pyriform in outline and fits closely into the small end of the pedicle valve, the expanded anterior part overlying the aulacotermia. The hinge is extremely narrow and straight. An interarea, or ginglymus, forms the posterior margin. On each extremity of the hinge is a small triangular lateral projection which is the articulating process. This fits into the socket at the anterolateral extremity of the pedicle valve palintrope. In some specimens the socket is further strengthened by a thickening on the margin of the aulacotermia where it terminates posteriorly at the socket. The lateral margins of the brachial valve, especially at the reentrant just anterior to the hinge where it is narrowest, is strengthened by a thickening. This extends anterolaterally along the margin of the expanding shell to about midvalve, where it generally dies out. These marginal thickenings correspond to the lateral ridges of the normal productid shell. The thickening is strongest and highest just anterior to the articulating process where the shell is narrowest and and probably helped in the articulation of the valves.

The cardinal process is erect, elongated, long-shafted, and bilobed in ventral view. In side view it is at an angle to the valve surface. The myophore is generally moderately lobed, with the lateral lobes moderately expanded but the median lobe narrow. The lateral lobes are moderately deeply grooved as usual in productids. The shaft bears a median groove. The cardinal process is buttressed by median elevation frequently consisting of two low parallel ridges that extend between the adductor scars. This unites with the brevisseptum to form a single long ridge, and is separate from it. The brevisseptum is usually short and terminates anterior to midvalve, but posteriorly extends between the adductors.

The anterior pair of adductors is the larger of the two. In *T. conida* the scars are large and somewhat

thickened but in some individuals of *T. boesei* they are long and narrow and moderately deeply inserted. The anterior slope of the valve is marked by large, stoutly pointed endospines of varying number depending on the species.

**GROWTH.**—The growth of the cup of *Teguliferina* is one of the main distinctions between this genus and the richthofeniids. The younger *Teguliferina* forms a very oblique cone in which the brachial valve is roughly parallel to the ventral side of the cone. The oblique position of the brachial valve is maintained throughout life, no matter how elongated the cone becomes. The cone is attached at the apex, but this part of the shell does not migrate aperturally as in the richthofeniids.

### *Teguliferina boesei* R. E. King

PLATE 203: FIGURES 4–25; PLATE 204: FIGURES 1–30; PLATE 207: FIGURES 28–38

*Teguliferina boesei* King, 1931:96, pl. 27: figs. 14–16.

*Planispina boesei* (R. E. King) Muir-Wood and Cooper, 1960, pl. 9: figs. 11–17.

Adult forming fairly symmetrical cone except for apex, that is twisted or deformed; young forming oblique cone. Height about three fourths of width. Posterior side of cone flattened, anterior side rounded. Apex usually deformed, attachment surface generally small. Initial and young anchor spines, rounded and slender; later attachments with strong broad webs forming after adulthood is reached. Anterior surface obscurely costellate.

Pedicle valve with strong aulacotermia and prominent concave, shelflike areas posterolaterally. Hinge very narrow. Hood strongly developed in early adultstage. Protective spines on anterior side slender to moderately stout, numerous, not completely covering the aperture. Outer anterior margin not strongly reflected.

Brachial valve gently concave to flat; surface finely papillose. Widest at midvalve, with the sides narrowly rounded and anterior broadly rounded.

Pedicle valve interior with lightly impressed muscle scars; interior spines moderately developed.

Brachial valve interior with large and erect cardinal process, long brevisseptum; no cardinal process buttress, and elongate adductor scars. Endospines few and large.



## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 701d							
151347a	13.4	11.1?	16.0	3.0?	13.4	4.1	2.8
151347b	12.6	10.1?	19.0	3.0?	13.4	5.5	3.8
151347c	14.4	12.5?	20.5	2.9?	12.2	6.2	3.8
151347d	16.9	13.1?	20.0	3.2	14.6	6.9	4.2
151347e	15.6	11.7	22.0	3.3?	14.4	6.8	4.8
151347f	17.0	12.2?	21.4	3.5?	15.6	8.7?	5.5
151347g	18.7	12.6	28.0	2.8	16.6	8.8?	6.5
151347h	17.6	11.0	22.0	3.1	18.8	9.0	5.1
151347i	14.7	11.9?	20.0	?	19.4	10.4	7.6
151347j	18.2	11.0	21.0	3.5?	23.0	15.0	4.4
151347k	18.5	12.6?	23.0?	?	20.0	10.5	7.0
151347l	15.0	?	24.0	?	17.2	16.0	6.9
151347m	19.1	?	28.0	?	20.6	18.0	9.6
151347n	15.8	?	?	?	20.1	14.0?	6.0
USNM 701h							
151349a	12.0	?	23.0	?	17.1	12.6	7.5
151349b	15.2	10.6?	21.0	2.9	17.1	9.6	6.5
151349c	13.2	10.3?	20.0	2.8	13.6	7.8	3.9
151349d	11.6	9.0?	14.0	2.0	12.9	7.0	3.5
151349e	9.4	7.4	13.0	2.7	9.5	3.8	3.5
151349f	7.9	5.0	9.0	?	6.8	2.9	2.3?
USNM 701k							
151352a	18.4	13.0?	29.5	?	26.3	18.4	?
151352b	15.9	?	26.0?	?	20.6	17.8	?
151352c	14.0	10.7?	15.0?	?	19.0	9.3	4.7
151352d	14.2	10.2	16.0	1.8	15.1	4.7	3.9
151352e	10.7	8.0	15.0	2.8	13.0	5.0	2.8
USNM 712w							
151362a	13.7	?	30.0	?	20.0	18.0	6.9
151362b	18.7	11.8	25.0	2.1	19.0	11.9	5.3
151362c	13.0	9.3	17.0	2.5	12.8	5.4	3.5

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (Virgilian), Gaptank Formation (*Uddenites*-bearing Shale Member), Neal Reach Formation; Lenox Hills Formation.

LOCALITIES.—Gaptank: USNM 700g, 701y. *Uddenites*: USNM 700i, 701e, 701f, 701p, 701q, 701t, 701v, 701x, 702j, 702n, 702q, 702r, 703p, 703x, 713b, 713o. Neal Ranch: USNM 701, 701a, 701a<sup>3</sup>, 701c, 701d, 701h, 701k, 701-l, 712w, 713h, 715b, 715e, 721g, 727d, 727e, 742c. Lenox Hills: USNM 705, 705k, 705m, 705s, 707j, 709t, 715, 716r, 723r, 737u.

DIAGNOSIS.—Fairly large *Teguliferina* with deep cups in the adult and prominent web-like spine attachments.

TYPES.—Holotype: YPM 12829. Figured paratypes: YPM 12661a, b. Figured hypotypes: USNM 151346a-c; 151347n; 151352d, e; 154091a-c, e-i; 154092a-h; 154093a-d, f; 154094a, c; 154095a, b; 154101a, b; 154110. Measured hypotypes: USNM

151347a-n, 151349a-f, 151352a-e, 151362a-c. Unfigured hypotypes: USNM 151347a.

COMPARISONS.—It is almost impossible to identify most young specimens of different species of *Teguliferina*. It is usually necessary to have the full growth series and also enough adult specimens to give a good idea of the full range of variation. As identified by us this species is represented in the collection by many hundreds of specimens of all sizes and a full range of variable adults. In its fully grown form this species is unlike *T. armata* of the Pennsylvanian of Illinois, Texas, and Kansas, which is fairly common in King's bed 10 of the Gaptank Formation (USNM 700, 700a) at the base of the hills 23 miles north-northeast of Marathon. Adult *T. armata* has a low, oblique cup with little or only moderate development of the hood. Complete cups rarely attain a height over 12 or 13 mm.

*Teguliferina boesei* attains a much larger size and the adult cup is usually much deeper.

*Teguliferina kansasensis* Girty attains a size equal to that of *T. boesei* but the three specimens of this species now known do not permit adequate comparison. All the specimens have a fairly broad apical region and form large, rapidly expanding cups, far more expanded and irregular in form than those of the majority of *T. boesei*.

*Teguliferina conida* (Stehli) is a well-formed and rounded cup, in profile suggesting a large *T. boesei*. It is, however, usually much larger; its young stage is generally more spreading and open than that of *T. boesei*, which is oblique and generally pointed at the apex. The shell of *T. conida* is much stouter and the spines more robust than those of *T. boesei*.

Of European species, *T. boesei* is most like *T. deformis* (Schellwien), type-species of the genus. The latter is commonly preserved in a hard massive reefy limestone which makes comparison with silicified material difficult. The figures by Schellwien indicate a less robust species than the Glass Mountains one, seldom attaining the size and spaciousness of the Texas species.

DISCUSSION.—Six localities in the Glass Mountains have yielded large collections of this species. Each was apparently the site of bioherms on which *Teguliferina* dwelt in abundance. Considerable variation may be seen among the specimens from each locality and among those from different localities. For example specimens from approximately the same levels at USNM 701h and 701k are much more delicate than the robust forms from USNM 712w. In spite of all the variables only one species seems to be represented from the *Uddenites* zone to the lower part of the Skinner Ranch Formation. Specimens from USNM 701 are generally more robust and solid than those from other localities. The explanation may be the difference in stratigraphic level, those from USNM 701 coming from the upper part of the Gray Limestone Member (bed 2 of P. B. King).

Like the adults, the young of this species are extremely variable; forms that are transverse are found side by side with elongate individuals. These variable young produce variable adults. Furthermore, no rule was discovered as to the size when the adult characters of protective spines and the beginning of a vestibule were initiated. These features appeared at lengths between 10 and 20 mm,

but mostly at about 15 mm. Specimens smaller than 10 mm generally do not have spines or a vestibule; however, specimens slightly above this length may develop protective spines, but the vestibule usually developed later. Some specimens attained a length of 20 mm without developing either a vestibule or the protective spines, but these are unusual.

That *Teguliferina* in the late Pennsylvanian and early Permian of the Glass Mountains favored a biohermal environment is clear from the Glass Mountains collections. Specimens in the shales of the *Uddenites*-bearing Shale Member of the Neal Ranch formation are rare and usually are not well-preserved. Most show evidence of transportation. Specimens are abundant in the limestones, commonly in masses or clusters but these do not retain their coherence when decalcified. Nevertheless, fairly large specimens showing the clustering habit have been recovered.

Large specimens of *Teguliferina* in the *Uddenites*-bearing Shale Member are referred here to *T. boesei*. These include large forms found with *Scacchinella primitiva* in the Virgilian (?) bioherm south of the Arnold Ranch (USNM 700g.) Bioherms of the Neal Ranch Formation abound in this species, but it is rare in the Lenox Hills Formation in which few silicified specimens were found. Inasmuch as the Lenox Hills formation is mostly conglomerate, specimens in it are loose or have drifted from nearshore bioherms.

### *Teguliferina compacta*, new species

PLATE 207: FIGURES 1-10

Small, thick-shelled, solid, forming well-rounded cones with eccentric apex; posterior side generally slightly or markedly flattened; anterior side rounded; cup opening commonly narrowed and covered by few stout protective spines. Cone-in-cone effect strong; successive rims preserved as ragged lamellae. Attachment surface small. Rhizoid spines stout, bound by flat webs. Interior and brachial valve not known.

MEASUREMENTS (in mm).—From locality USNM 705r, specimens 151370a (holotype), b, and c, respectively: length 12.8, 14.8, 15.5; surface length 20.0, 16.0, 21.5; width 12.2, 18.2, 18.2; height 15.0, 16.4, 15.0?

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (top); Hess Formation (Taylor Ranch Member).

LOCALITIES.—Skinner Ranch: USNM 705r. Taylor Ranch: USNM 702d, 702e, 723-1.

DIAGNOSIS.—Small, compact *Teguliferina* with ragged exterior.

TYPES.—Holotype: USNM 151370a. Figured paratypes: USNM 151370b, c. Measured paratypes: USNM 151370b, c.

COMPARISON.—The thick shell, low cone, and stout rounded form of this species, with the few protective spines over the cup, separate it from any of the Texas or European forms.

DISCUSSION.—This species is rare and is not favorably preserved because it is generally covered and often filled with gray siliceous material that is interpreted to be silicified algae that have grown over the dead shells. These algae make it difficult to recover complete specimens and may be the reason that the dorsal valve has not yet been seen.

*Teguliferina conida* (Stehli)

PLATE 89: FIGURES 31–33; PLATE 205: FIGURES 1–35; PLATE 206: FIGURES 1–43; PLATE 309: FIGURES 7–14

*Planispirina conida* Stehli, 1954:332.—Muir-Wood and Cooper, 1960, pl. 9: figs. 18, 19.

Large thick-shelled *Teguliferina* broadly oblique in young but forming misshapen cone in adults;

aperture of cone flattened to concave on dorsal side; place of attachment varying from point to broad patch; apex usually distorted. Growth cylindrical after development of hood. Anchor spines stout and round in young, strengthened and partially covered by webs and sheets of shell tissue. Surface mostly concentrically marked except on dorsal side, which is obscurely costellate in some specimens. Anterior side with strong cone-in-cone development.

Pedicle valve with stout protective spines on anterior side, varying from oblique and single to branching and occasionally anastomosing. Hood formed after attainment of maximum width, usually flattened to concave; anterior side strongly convex and rounded. Lip of cup not greatly expanded.

Brachial valve widely pear-shaped and with short posterior neck; hinge narrow. Surface varying from slightly convex to gently concave; sides narrowly rounded; anterior margin broadly rounded to subtruncate.

Pedicle valve interior with muscle area moderately to strongly thickened; internal spines numerous and large.

Brachial valve interior with large cardinal process; buttress ridge strong; brevisseptum strong and anteriorly elevated; adductor scars elongated; endospines few and large.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 705a							
151375a	17.4	?	30.0	?	24.8	21.1	?
151375b	20.0	14.1	27.0	2.9	23.8	15.8?	?
151375c	19.4	12.0?	32.0?	?	20.6	17.2	6.7
151375d	25.1	11.6?	31.5	3.5?	26.9	18.0	7.4
151375e	22.3	13.0	27.0?	3.6	23.2	14.3	6.4
151375f	16.8	?	26.0	?	22.3	15.2	?
151375g	21.0	15.0	27.0	3.9	22.1	10.5	6.1
151375h	16.0	11.0?	22.0	3.3?	18.9	11.2	5.0
151375i	19.0	13.3	24.0	4.0	23.6	10.7	2.1
USNM 728f							
152686a	16.0	12.0	18.0	4.9	19.7	6.0	4.0
152686b	14.0	8.3?	25.0?	?	20.0	14.4	6.1?
152686c	18.6	13.7?	27.0	3.5?	20.7	17.0	8.0
AMNH 625							
123889	20.6	?	?	?	22.6	18.8	?

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation, Skinner Ranch Formation (base), Cibolo Formation (Breccia Zone of Udden).

LOCALITIES.—Bone Spring: AMNH 625, 629, 631,

632, 696; USNM 725c, 728e, 728f, 746. Skinner Ranch: USNM 705a, 707b, 709v, 714p, 715v, 720e, 724p, 733r. Cibolo: USNM 728–1, 738r.

DIAGNOSIS.—Stout, thick-shelled *Teguliferina*

with strong cone-in-cone effect and ragged posterior sides.

**TYPES.**—Figured hypotypes: USNM 123889; 151375a, c-e, i, j; 155149; 154096a-h, j, m; 154097a-d; 154098a, b; 154099a-c; 154111. Measured hypotypes: USNM 123889; 151375a-i; 152686a-c.

**COMPARISON.**—Differences between *T. conida* (Stehli) and *T. boesei* R. E. King appear in young and old specimens. The young of the former are usually rounder and more open than those of *T. boesei*, and much less oblique. Furthermore, the appearance of the hood and protective spines appears to take place at an earlier time or smaller size than in *T. boesei*. Although adults of both species have a similar habit, the cup of *T. conida* attains a much larger size and a greater diameter. Furthermore the protective spines are commonly larger and thicker than those of *T. boesei*. The cone-in-cone feature in the shell growth is more developed in most specimens of *T. conida* than in *T. boesei* and produces a shell with a ragged dorsal side. This feature occurs in most species of *Teguliferina* but it is especially marked in *T. conida* because of its large size and compact form.

**DISCUSSION.**—*Teguliferina conida* was described by Stehli (1954:332) under the generic name of *Planispina*, in allusion to the prominent webs on the spines. Inasmuch as these occur in the Pennsylvanian species and also the European type species, they do not constitute a valid generic character in this case. *Teguliferina conida* is identified in the Glass Mountains in the *Scacchinella* zone (base of Skinner Ranch Formation), as well as in the

Bone Spring Formation of the Sierra Diablo. Specimens in the Glass Mountains attain a somewhat larger size and more robust form but other features appear to be alike, making separation as different species unlikely.

### *Teguliferina parva*, new species

PLATE 207: FIGURES 11-18

Small, forming posteriorly flattened cones having length and height about equal. Hood margin somewhat flattened; spines on anterior inside margin numerous, moderately stout and inclined away from aperture; sides narrowly rounded. Surface with posterior side ragged, anterior side fairly smooth. Anchor spines of young specimens round, slender; older specimens with well-developed sheets of rhizoid tissue forming webs between spines.

Pedicle valve with apex misshapen, attachment surface varying from small to nearly entire posterior surface. Ragged zone on posterior side approximating half height of adult, having many closely crowded lamellae. Aulacotermia thick; posterolateral concave areas large.

Brachial valve compressed, pear-shaped, with very narrow hinge and narrowed apical region. Sides narrowly rounded and interior broadly rounded.

Pedicle valve interior with very narrow hinge; muscle scars not strongly impressed. Brachial valve interior with large, erect cardinal process, no median buttress ridge to cardinal process; long brevisepitum; elongate adductor scars. Few endospines.

#### MEASUREMENTS (in mm).—*Teguliferina parva*, new species:

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 761							
151372a	9.9	?	15.0	?	12.7?	9.7	?
151372b	11.4	?	21.0	?	16.0	10.4	?
151372c	11.3	?	15.0?	?	14.8	11.0	?
151372d	9.9	7.3	13.5	2.8	14.2	6.5	4.0?
151372e (holotype)	10.2	8.2	13.5	2.6	14.9	5.5	3.6

**STRATIGRAPHIC OCCURENCE.**—Wolfcampian (Red Eagle Limestone).

**LOCATION.**—USNM 761.

**DIAGNOSIS.**—Small *Teguliferina* with flattened cones and wide brachial valves.

**TYPES.**—Holotype: USNM 151372e. Figured paratypes: USNM 151372a, c, f. Measured paratypes: USNM 151372a-d.

**COMPARISONS.**—The small size and flattened nature of the cones of this species separate it from the



other Permian species which are larger and generally deeper. Fully grown cups of this species attain only about half the length of *T. boesei* or *T. conida*.

DISCUSSION.—This species has somewhat different ecology from that of other Permian species, which are commonly bioherm dwellers. *Teguliferina parva* occurs commonly in small spreading clusters on a limy mud base. The clusters have little depth and are usually only one cup deep. Specimens are commonly found in small patches which could not have had much effect on the bottom. Other genera of brachiopods are rarely associated with the clusters.

### *Teguliferina solidispinosa*, new species

PLATE 207: FIGURES 19–27

Fairly large for genus, robust and thick-shelled; width greater than length; cups irregular, with ragged dorsal side; aperture elliptical, wider than long, narrowly reflected lip. Attachment surface large; hood long and flattened. Anchor spines thick, long, and with abundant webs and attachment sheets. Apertural spines thick, crowded, often united distally, laterally attaching to inner wall of posterior side to form excurrent channel.

Brachial valve thin and delicate, with strong median ridge and large elevated cardinal process.

MEASUREMENTS (in mm).—From locality USNM 701c, specimens 154100a (holotype) and b, respectively: length 18.0, 13.1; brachial valve length 17.0?, (?); surface length 15.0?, 19.0; hinge width 3.3, (?); height 15.0, 15.0; thickness 7.0?, (?).

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation.

LOCALITY.—USNM 701c.

DIAGNOSIS.—Thick-shelled *Teguliferina* with spines covering aperture.

TYPES.—Holotype: USNM 154100a. Figured paratypes: USNM 154100a, c. Measured paratype: USNM 154100b.

COMPARISON.—This species differs from others in the almost complete covering of the apertural spines over the cup and the fusing of their ends distally and laterally with the walls of the cup.

DISCUSSION.—This species is strongly reminiscent of *Taphrosetria*, new genus, in the construction of the spines and the channel they form for excurrent stream. The species does not have the regular development of residual apertural flanges (cone-in-

cone) seen in *Teguliferina* (Stehli). The web development is so strong on and between the spines that specimen 154100b shows sheets covering the host. In specimen 154100a the early rhizoid spines are very slender but are preserved behind a sheet or wall formed by the welding of the spines together by attachment shell.

### Genus *Acritosia* Cooper and Grant, 1969

*Acritosia* Cooper and Grant, 1969:5.

Small to moderately large variable cones having protective spines on anterior side only; cones oblique in youth but even and nearly circular in adults. Margin of cup with slight flare. Brachial valve oblique within cup; vestibule deep. Exterior with strong concentric wrinkles; rhizoid spines stout, circular in cross section.

Pedicle valve interior with strong aulacotermia; apex only slightly thickened; pseudodeltidial region short and confined to apical region, not migrating dorsally. Muscle region not strongly thickened.

Brachial valve flat to slightly concave, with moderately long neck. Cardinal process like that of *Teguliferina*, erect, shaft short; muscle region slightly thickened, scars separated by low double ridge. Endospines few, strong.

TYPE-SPECIES.—*Acritosia magna* Cooper and Grant, (1969:6, pl. 5: figs. 17, 18).

DIAGNOSIS.—*Teguliferinidae* with rhizoid spines having circular cross section and without strengthening webs.

COMPARISON.—This genus is intermediate between *Teguliferina* and *Cyclacantharia*. It is distinguished from *Teguliferina* by its round anchor spines, whereas the other genus has flat, weblike attachment spines. *Acritosia* is unlike *Hercosia* in lacking the strong apical septum of that genus, but it may be confused with *Cyclacantharia*, which likewise does not have a median septum.

*Cyclacantharia*, however, differs from *Acritosia* in having a complete circle of protective spines around the inner margin of the aperture and is provided with a prominent muscle mound at the apex of the pedicle valve. Furthermore, the pedicle valve of *Acritosia* does not migrate dorsally as the shell advances in age, a feature linking it with the *Teguliferinidae*.

DISCUSSION.—As presently constituted this genus includes species that are strongly contrasting in their appearance. The type species is large, thin-shelled, and variable; *A. peculiaris*, new species, is strongly flattened; *A. solida* and *A. vestibula*, both new, are thick-shelled; and *A. teguliferoides* (R. E. King) is small, stout, and oblique. In spite of these marked differences they have many characters in common. All are strongly oblique in youth and have the brachial valve apically hinged as in *Teguliferina*. With growth, this valve maintains its apical position or migrates very slightly. It never migrates to the extent seen in *Cyclacantharia*, *Hercosia*, or other Richthofeniacea.

### *Acritosia magna* Cooper and Grant

PLATE 199: FIGURES 1–29

*Acritosia magna* Cooper and Grant, 1969:6, pl. 5: figs. 17, 18.

Large, thin-shelled cones varying from high to somewhat spreading; anterior side flattened; pos-

terior side broadly rounded. Apex small, bluntly pointed, directed posteriorly; attachment surface small. Young forming wide, spreading, oblique cones. Surface wrinkled and with concentric lines of growth. Rhizoid spines round and slender.

Pedicle valve with numerous short, stout spines on inside margin of anterior side; aulacotermia well marked and extending obliquely around inside of cup, lying just posterior to the protective spines on anterior side. Muscle field not thickened, but with low median myophragm. Interarea small; posterolateral flattened areas small or nearly obsolete.

Brachial valve nearly flat; transversely pear-shaped, sides extended and narrowly rounded; anterior margin gently rounded to nearly straight. Posterior extension short.

Brachial valve interior with narrow and erect cardinal process; buttress ridge low or nonexistent. Brevisseptum low and obscure. Adductor scars slightly thickened, elongate.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 701h							
151737a	24.5	?	33.0	5.0	27.9	24.0	?
151737b	26.2	16.4	33.0	4.3	26.3	18.6	?
151737c	32.3	18.7	43.0?	4.2	33.0	27.4	2.7
151737d	28.7	?	31.0	?	28.5	22.0	?
151737e	31.4	?	42.0	?	27.0	37.3	?
151737f	20.9	?	31.0	?	22.3	22.6	?
USNM 701k							
151739a	23.0	15.0?	31.0	4.0	25.2	18.0	?
151739b	24.0	?	43.0	?	24.8	25.4	?
151739c	20.6	?	40.0	?	27.4	25.6?	9.0
151739d	17.8	12.4?	24.0	5.0	28.6	14.4	6.1
151739e	20.7	?	30.0	?	36.4	14.3	?
USNM 701g							
151735a (holotype)	18.0	?	28.0?	?	28.2	22.0	?

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (beds 9–14).

LOCALITIES.—USNM 701c, 701g, 701h, 701k.

DIAGNOSIS.—Wide, thin-shelled *Acritosia* with flaring cups.

TYPES.—Holotype: USNM 151735a. Figured paratypes: USNM 151734; 151737e; 151738; 151739b, e, f, h; 154043a, b; 154044a, b, d. Measured paratypes: USNM 151737a–f, 151739a–e. Unfigured paratypes: USNM 151737a–d, f; 154044c, e;

COMPARISON.—The large size and thin shell distinguish this species from all others of the genus. The species can be confused only with *A. peculiaris*, new species, which is similar in size but has a thicker shell, stouter protective spines, and less flared aperture.

DISCUSSION.—This is the largest of the *Teguliferinidae* occurring in the Wolfcampian (Neal Ranch Formation). It occurs intimately intergrown in large “colonies” of *Teguliferina boesei* R. E. King.

*Acritosia magnifica*, new species

PLATE 308: FIGURES 24-27

Large, bluntly conical, starting as squat, spreading cup, attaining maximum width early and then growing vertically; apical angle near or above  $100^\circ$ , length and width nearly equal; sides strongly wrinkled but with only small cone-in-cone effect. Surface strongly wrinkled; rhizoid spines scattered over entire cup, very thin. Protective spines only on anterior side of cup. Apex small with very small cicatrix. Brachial valve deeply inset, not granulose, with strongly and narrowly convex shoulders. Sides narrowly rounded, anterior margin broadly rounded.

Interior of pedicle valve with small aulacotermia; floor with somewhat thickened muscle region. Details of brachial valve not preserved.

MEASUREMENTS (in mm).—From locality USNM 724j, specimens 154055a and b (holotype), respectively: length 25.5, 26.4; brachial valve length (?), 18.0; width 32.3, 31.4; thickness 20.6, 13.4; height 35.4, 23.2; aperture width 27.5, 26.3; aperture length 18.4, 24.4.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITY.—USNM 724j.

DIAGNOSIS.—The largest species of *Acritosia*, with rapidly expanding cup in the young but long and cylindrical in the adult.

TYPES.—Holotype: USNM 154055b. Figured paratype: USNM 154055a.

DISCUSSION.—This is an unusual species for its shape, size, and combination of characters. The cup starts off initially as a low, squat cone which expands rapidly reaching its maximum width at an early age, e.g., in specimen 154055a, at about one-third the height of the cup. The anchor spines are very slender and delicate for such a large shell. The brachial valve has strongly rounded shoulders that fit into the reentrant formed by the flat areas, large

in this species, bounding the hinge.

These specimens are referred to *Acritosia* because their protective spines are located on the ventral side only and there is no strong median septum as in *Hercosia*. A fair-sized muscle mound can be seen in a crack in the holotype and is suggestive of a trend toward *Cyclacantharia*. Another feature linking it to *Acritosia* is the small development of cystose shell located mainly in the apical part of the cone.

*Acritosia peculiaris*, new species

PLATE 201: FIGURES 1-45

Large cones, variable, oblique to erect, with wide apical angle and large, somewhat flared aperture. Brachial valve strongly oblique within cup, thus defining shallow vestibule. Hood long, flat to concave. Cross section broadly to somewhat narrowly elliptical. Sides rounded, but anterior and posterior slightly to strongly flattened. Protective spines stout, short, anastomosing. Surface concentrically wrinkled; rhizoid spines slender. Apex not strongly thickened by cystose shell.

Brachial valve flattened posteriorly, concave anteriorly with short, narrow, neck and sloping shoulders. Sides rounded to subtruncate; anterior margin nearly straight. Surface coarsely papillose to spinose in young, strongly and thickly papillose in adults.

Pedicle valve interior with strong and oblique aulacotermia located just under spine row on anterior side; muscle mound low, with diductor scars clearly defined on each side. Posterolateral areas not strongly developed.

Brachial valve interior with large and erect cardinal process buttressed posteriorly by lophidium; lateral ridges moderately well developed; median buttress ridge strong, continuous with brevisseptum. Endospines stout, few in number, forming one or two rows.

MEASUREMENTS (in mm).—*Acritosia peculiaris*, new species:

	apical angle	length	brachial valve length	brachial valve width	surface length	hinge width	mid- width	height	thickness	aperture length	aperture width
USNM 707g											
151776a	$43^\circ$	20.0	15.0?	24.0	46.0	6.0?	32.2	30.3	?	20.0	31.5
151776b	$60^\circ$	25.1	18.0	23.5	45.0	6.0	28.7	17.6	?	24.0	99.0
USNM 707ha											
151756a (holotype)	$51^\circ$	21.4	18.5	22.0	33.0	6.2	26.5	33.0	20.0?	16.6	29.7
151756b	$42^\circ?$	22.4	20.0	22.5	37.0	5.3	25.5	25.0	13.5	23.6	26.9

**STRATIGRAPHIC OCCURRENCE.**—Lenox Hills Formation, Bone Spring Formation, Skinner Ranch Formation (Dugout Mountain, Decie Ranch, Poplar Tank and Sullivan Peak members), Hess Formation.

**LOCALITIES.**—Lenox Hills: USNM 705m. Bone Spring: USNM 725c, Dugout Mountain: USNM 733–1. Decie Ranch: USNM 707a, 707g, 708q, 714t, 716p, 720f, 720g, 727u. Poplar Tank: USNM 707h, 707ha, 708e, 710x. Sullivan Peak: USNM 707d, 707x, 710d, 714y, 715j, 722h, 722–1, 727a, 733j, 739g. Skinner Ranch: AMNH 504, 520; USNM 705n, 715n, 723s. Skinner Ranch (low): USNM 711d, 712p, Skinner Ranch (top): USNM 705r, 710r, 722m, 723–1, 726h, Hess: USNM 702d, 716o, 716n, 726n.

**DIAGNOSIS.**—Large *Acritosia* with anteriorly concave brachial valve, poorly developed posterolateral areas and large, erect cardinal process.

**TYPES.**—Holotype: USNM 151756a. Figured paratypes: USNM 151756b; 151776a, b; 154045a–h; 154046a, b, d; 154047; 154048. Measured paratypes: USNM 151756b; 151776a, b. Unfigured paratypes: USNM 154046c.

**COMPARISON.**—Of all species of *Acritosia* this one may be compared to *A. magna* Cooper and Grant, which it approaches or equals in size. The differences between the two are discussed under *A. magna*.

**DISCUSSION.**—The shortness of the body chamber helps to identify this species in unsilicified specimens or those in matrix. Large specimens from the

Decie Ranch Member are placed here although it has not been possible to see details of the interior.

### *Acritosia silicica*, new species

PLATE 200: FIGURES 1–29; PLATE 309: FIGURES 1–5

Average size for genus, forming oblique cones approximating angle of 90° in adults; sides fairly straight; apex bluntly pointed; aperture roundly elliptical, margins strongly flaring in many specimens. Anterior side of aperture with moderately long, rather delicate, pointed spines. Surface rugose, undulations interrupted and irregular. Rhizoid spines numerous, rounded in section but thin and delicate.

Pedicle valve with irregular lateral profile, umbonal region usually flattened, median region narrowly rounded and anterior slope long, flattened or gently convex. Posterior side short and flattened; hinge sockets wide and deep. Aulacotermia well-defined. Muscle region medially thickened.

Brachial valve flat to gently concave, usually somewhat geniculated anteriorly toward dorsal direction. Hinge very narrow, forming moderately long neck; anterior and anterolateral margins deflected. Brachial valve interior with long, slender, narrowly compressed cardinal process; long shaft marked by median groove extending anteriorly into median ridge thus forming two parallel elevated lines extending nearly to mid-valve; endospines long and delicate.

#### MEASUREMENTS (in mm).—*Acritosia silicica*, new species:

	apical angle	length	brachial valve length	brachial valve width	surface length	hinge width	mid- width	height	thickness	aperture length	aperture width
USNM 725b											
152687a	61°	9.4	7.2	8.8	18.0	?	12.4	10.0	5.8	7.7	9.7
152687b	70°	13.5	?	?	18.5	4.2	17.2	9.3	?	6.5	8.7
152687c (holotype)	88°	15.0	9.7	11.3	22.0	2.4	17.6	7.9	3.6	9.4	13.0
152687d	91°	15.3	?	?	17.0?	4.0	19.7	10.7	?	11.5	13.7
152687e	91°	15.0	?	?	24.5	3.7	17.9	8.4	?	9.6	14.1
152687f	70°	10.5	?	?	14.5	2.7	12.8	6.9	?	7.0	9.6
152687g	80°	14.3	10.6	13.2	21.5	3.6	19.0	10.0	4.3	8.8	12.4
152687h	70°	17.7	10.2?	13.2	28.0	?	20.6	12.4	6.0	9.1	13.0

**STRATIGRAPHIC OCCURRENCE.**—Hueco Formation (upper), Cibolo Formation.

**LOCALITIES.**—Hueco: AMNH 700; USNM 725b. Cibolo: AMNH 703.

**DIAGNOSIS.**—Medium-sized *Acritosia* forming

round oblique cones with moderately deep vestibule and moderately flaring apertural margins.

**TYPES.**—Holotype: USNM 152687c. Figured paratypes: USNM 152687a, b, d, g, h, o, q, s–v, x. Measured paratypes; USNM 152687a, b, d–h. Un-



figured paratypes: USNM 152687e, f, i–n, p, r, w.

COMPARISON.—This species suggests *Teguliferina boesei* R. E. King, but that species has webbed rhizoid spines. It is most like *A. teguliferoides* (R. E. King) but that species is more oblique, usually smaller and has a thick mat of rhizoid spines as anchors. It is much smaller and more oblique than *A. magna* Cooper and Grant, or *A. peculiaris* and *solida*, new species.

DISCUSSION.—This species is abundant in a small patch at USNM 725b. It evidently lived in intimate masses because specimens of all sizes and shapes were recovered from the residues. Many young specimens show the initial form to have been circular but unfavorable position caused many of them to be elongated on further growth. The hinge sockets of the pedicle valve in the young have a strong anterior marginal rim.

### *Acritosia solida*, new species

PLATE 202: FIGURES 43–61

Fairly large, thick-shelled cones rounded on anterior side but flattened to concave on posterior side, apex twisted strongly toward posterior, small point of attachment. Hood in adults usually strongly concave. Aperture usually strongly flattened on anterior side. Surface strongly wrinkled, with cone-in-cone effect marginally. Rhizoid spines generally rounded and slender.

Pedicle valve with deep vestibule; aulacotermia strong; posterolateral areas poorly developed; muscle field not strongly thickened. Interior spines numerous and long. Protective spines thick.

Brachial valve widely pyriform with narrowly rounded sides and broadly rounded anterior margin. Profile nearly flat. Cardinal process large, erect, buttressed by double median ridge. Lateral ridges strong; adductor scars elongate. Endospines few and large.

MEASUREMENTS (in mm).—Brachial valve length and thickness unmeasurable.

	length	surface length	hinge width	mid- width	height
USNM 702d					
151741a	14.0	30.0	4.3	23.6	16.8
151741b	18.0	29.0	5.0	22.4	16.4
151741c	14.0	23.0	?	13.7	18.0
151741d	18.4	27.0	?	28.0	20.2
151740b	18.2	34.0	?	28.2	22.5
(holotype)					

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Dugout Mountain Member), Hess Formation (Taylor Ranch Member).

LOCALITIES.—Skinner Ranch: USNM 727f. Dugout Mountain: USNM 732e. Taylor Ranch: USNM 702d, 716n, 716o.

DIAGNOSIS.—Thick-shelled and large *Acritosia* with strongly concave posterior side.

TYPES.—Holotype: USNM 151740b. Figured paratypes: USNM 151740a; 151741a–c, e, g. Measured paratypes: USNM 151741a–d. Unfigured paratypes: USNM 151740a; 151741d, f.

COMPARISON.—This is a stout-shelled species of moderate size strongly resembling *Hercosia uddeni* (Böse). It differs from that species in not having a median septum, in having much stouter and fewer protective spines, and in a nearly apical brachial valve articulation.

This species is much larger than *A. teguliferoides* (R. E. King) and also *A. vestibula*, new species. The latter has rounder and more compact cups than *A. vestibula*, whereas *A. teguliferoides* is oblique and strongly reminiscent of *Teguliferina*.

### *Acritosia teguliferoides* (R. E. King)

PLATE 200: FIGURES 30–34; PLATE 202: FIGURES 1–42; PLATE 203: FIGURES 1–3, 26–40; PLATE 284: FIGURES 34, 35

*Prorichthofenia teguliferoides* R. E. King, 1931:99, pl. 30; figs. 2–7.

*Teguliferina? teguliferoides* (R. E. King) Stehli, 1954:330, pl. 24: figs. 5–8.

Small, oblique, thick-shelled cones cemented by small, bluntly pointed apex which is directed posteriorly; aperture flattened on posterior side but well rounded on opposite side. Hood flattened to concave. Anchor spines slender, round and numerous.

Pedicle valve interior with numerous protective spines on inside of anterior margin; aulacotermia strong; posterolateral areas concave and prominent; muscle impressions not strong; myophragm weak.

Brachial valve pyriform in outline, flat to concave in profile. Side narrowly rounded and anterior broadly rounded; posterior moderately extended and narrow.

Brachial valve interior with elevated cardinal process buttressed by low median ridge continuous with brevisseptum. Lateral ridges strong.

## MEASUREMENTS (in mm.)—

	length	brachial valve length	surface length	width hinge	midwidth	height	thickness
AMNH 625							
151752a	13.2	9.7	23.0	?	16.9	12.6	7.0
151752b	11.8	9.8	18.0	?	15.7	11.0	6.2
AMNH 628							
151753a	12.9	10.3	21.0	4.1	17.5	11.6	7.5
151753b	14.7	?	26.0	?	19.5	13.8	?
151753c	12.4	11.0	21.5	3.2	15.7	8.4	6.1
151753d	9.6	8.0	17.0?	2.4	11.4	7.2	5.9

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation (lower), Skinner Ranch Formation (Decie Ranch Member), Cibolo Formation.

LOCALITIES.—Bone Spring: AMNH 625, 628, 629, 631, 660; USNM 728e, 728f, 728h. Decie Ranch: USNM 707a, 707w, 708q. Skinner Ranch (base): AMNH 520; USNM 705a, 705o, 709u, 711i, 711p, 715v, 720e. Cibolo: 728-l, 738f, 738r.

DIAGNOSIS.—Small, stout, thick-shelled *Acritosia* with a thick brush of attachment spines on all sides of the pedicle valve.

TYPES.—Lectotype: YPM 11957a. Figured paratype: YPM 11952, 11957b, T11064. Figured hypotypes: AMNH 27312/1-3 and USNM 153674; 154049a-d, f, h, i, k; 154050a-f; 154052a, b, d, e; 154058a-i, l, m. Measured hypotypes: USNM 151752a, b; 151753a-d.

COMPARISON.—This is a small and strongly oblique *Acritosia*, having about the same size as *A. vestibula*, new species. It appears to be more oblique and to have a narrower and more pointed apex than that of *A. vestibula*, which is fairly well-rounded apically. It also possesses a heavier mat of anchor spines than the Road Canyon species.

DISCUSSION.—King failed to designate a type for his species and Stehli (1954) also did not select a type from King's lot. We therefore select a specimen illustrated by R. E. King (1931, pl. 30: figs. 3a-b) from the Sierra Diablo (R. E. King 479) as lectotype. This specimen shows the strongly oblique form and has a remnant of the brachial valve preserved. It also has a trace of the spines on the anterior margin of the cup.

*Acritosia? vestibula*, new species

PLATE 294: FIGURES 1-16; PLATE 308: FIGURES 1-5

Small variable cones with wide aperture but

usually with posterior side flattened or concave; vestibule deep; hood usually low and depressed anteriorly. Anterior marginal wall of cup with row of long delicate spines at high angle to axis. Apex bluntly pointed, straight, small, commonly incurved. Aperture not flaring. Surface with concentric wrinkles, cone-in-cone feature not developed. Rhizoid spines delicate.

Pedicle valve interior with aulacotermia well developed, located well down in vestibule below spine row. Posterolateral areas large, flattened. Pseudodeltidial area short, open to interior. Muscle region not thickened; muscles commonly inserted in deep apical pit. Interior spines present.

Brachial valve flat to slightly concave; not papillose externally in adults. Neck short, not deeply excavated; shoulders nearly straight; sides narrowly rounded, anterior margin nearly straight to gently rounded.

Brachial valve interior with delicate cardinal process covered by chilidium; median ridge obscure; adductor scars not thickened.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 702c, 709c, 710u, 724a, 724d.

TYPES.—Holotype: USNM 151743b. Figured paratypes: USNM 151742a, b; 151743a, b, f, h-j. Measured paratypes: USNM 151743a, c-i. Unfigured paratypes: USNM 151743c-e, g.

DIAGNOSIS.—This species is distinguished by its deep vestibule, delicate spines, and flat or concave posterior side.

DISCUSSION.—This is a rare species and not entirely characteristic of the genus. It is placed tentatively in *Acritosia* because it lacks the strong median septum of *Hercosia*. It is not so oblique as normal in *Acritosia* and the brachial valve is not obliquely placed. It cannot be assigned to *Cyclacan-*

## MEASUREMENTS (in mm).—

	apical angle	length	brachial valve length	brachial valve width	surface length	hinge width	mid- width	height	thickness	aperture length	aperture width
USNM 702c											
151743a	58°	13.3	10.0?	11.5	22.0	4.0	14.9	13.6	6.0	12.0	16.2
151743b (holotype)	37°	13.8	10.0?	11.0	23.0	4.5	15.0	17.5	10.8	8.8	15.0
151743c	56°	11.3	8.8	10.5	19.0	3.8	13.4	9.7	6.9	12.2	14.4
151743d	44°	13.2	10.0	12.0	21.0	3.8	15.0	15.0	10.7	12.2	14.0
151743e	46°	13.7	9.0	11.0	20.0	3.3	14.0	13.0	7.3	9.5	15.0
151743f	34°	13.5	10.0	11.5	23.0	3.8	15.0	16.0	9.2	14.0	16.0
151743g	54°	12.0	9.0	11.0	23.0	2.8	14.5	14.6	8.3	12.3	14.7
151743h	54°	11.4	9.5	10.0	19.0	2.5	13.0	10.0	7.5	11.0	12.0
151743i	54°?	7.8	7.0	6.5	1.5	2.0	7.7	5.5	3.9	9.3	8.7

*tharia* because it does not develop spines around the whole inside of the aperture.

attached productidiniids. We therefore eliminate this family from the Aulostegacea.

### Superfamily AULOSTEGACEA Muir-Wood and Cooper, 1960

[Ex Aulostegidae Muir-Wood and Cooper, 1960]

Productida derived out of Stropholosiacea by reduction and elimination of teeth and sockets, modification of the pseudodeltidium, and elimination of the chilidium but retaining the ventral interarea. Usually attached initially but may live free if broken from mooring.

This superfamily is established for the large number of genera having the palintrope well defined, the interarea with the delthyrium open or closed by an elytridium, and a lophidium. In the young stages these brachiopods are attached by beak cementation, buttressed by rhizoid spines. Many lived attached throughout their lives but others lived free on the sea bottom after having been ripped from their moorings.

Families represented in the Glass Mountains are: Cooperinidae, Aulostegidae, Spyridiophoridae, Tschernyschewiidae, and Scacchinellidae.

In the *Treatise on Invertebrate Paleontology* (part H, 1965:H460) the family Chonetellidae is classified among the Strophalosiacea and is placed between the Spyridiophoridae and the Tschernyschewiidae. This is certainly a poor placement because that genus has no strophalosiid characters. Moreover it was not an attached form and must have lived like the marginiferids or other small un-

### Family COOPERINIDAE Pajaud, 1968

[Ex Cooperininae Pajaud, 1968]

Small to minute, cemented by large cicatrix and anchored by rhizoid spines; brachial valve with prominent erect trilobed cardinal process. Pedicle valve with platelike palintrope having smooth interarea. No elytridium. Brachial ridges present.

Genera in West Texas: *Cooperina* Termier, Termier, and Pajaud, 1966; and *Atelestegastus*, new genus.

The first genus is very common in the Willis Ranch Member of the Word Formation, but is less common elsewhere. It appears to have originated in the Pennsylvanian because several specimens were taken in the Pawnee Formation (Labirdie Member) from Nowata County, Oklahoma. These belong to "*Leptalosia*" *spondyliiformis* (White and St. John) as figured by Dunbar and Condra (1932). The brachial valves of the Oklahoma specimens have the same adductor platforms as the Permian species. In the Permian it occurs in Wolfcampian sediments as well as in the higher formations. *Atelestegastus* also may occur in the Pennsylvanian as indicated by externally similar specimens from the Pawnee Formation in Oklahoma.

We do not agree with the opinion of the Termiers and Pajaud that *Cooperina* belongs in the Thecideidina. This little genus has all of the distinguishing characters of the Productidina as ex-

plained by Cooper and Grant (1969:17) and elaborated below.

**Genus *Cooperina* Termier, Termier, and Pajaud, 1966**

*Cooperina* Termier, Termier, and Pajaud, 1966:332–335.—  
Cooper and Grant, 1969:17.

Small, attached by umbonal part of pedicle valve; subrectangular in outline; hinge equal to or less than midwidth; pedicle valve surface spinose but not costellate; rhizoid spines confined to ears and umbo; ornament spines long and slender, curving over anterior margin; brachial valve surface with scattered spines.

Pedicle valve strongly convex and deep; palintrope thin and flat, without delthyrium; interarea flat; teeth absent; anterior half marked in older specimens by low, thick median ridge extending nearly to midvalve.

Brachial valve flat to gently concave, smooth or with fine spines in well-preserved specimens; cardinal process large, laterally expanded, bilobed to quadrilobed, lobes widely divergent; visceral region enclosed by elevated, submarginal rim diverging from base of cardinal process and united anteriorly to form median ridge extending to midvalve; median ridge grooved anteriorly; adductors attached to thin elevated platforms attached partly to valve floor and partly to lateral submarginal ridge; brachial ridges indistinct, elongated.

**TYPE-SPECIES.**—*Cooperina inexpectata* Termier, Termier, and Pajaud (1966: 332–335).

**COMPARISONS.**—*Cooperina* is characterized by its attached habit, spinose pedicle valve and spiny brachial valve, lack of teeth in the pedicle valve or sockets in the opposite valve, the flangelike submarginal ridge, short but prominent median ridge, and the elevated, excavate adductor platforms.

Absence of teeth and sockets indicates relationship of *Cooperina* to the Aulostegacea but the adductor platforms and lateral flanges as well as the peculiar median ridge set it apart from all members of that family. The interior of the brachial valve has some features that are prophetic of the Thecideidae, although probably not ancestral.

**DISCUSSION.**—Although many hundreds of specimens of this genus were examined, it was not possible to determine some features in detail. It was not possible to make out clearly the form of the ventral muscle scars. The presence of a short obscure median ridge indicates the presence of the adductors in the umbonal cavity but not one specimen revealed their form. The diductor scars are equally obscure but faint markings on both sides of the posterior half of the interior indicate these muscles to have been large and strong, as usual in the Productidina.

Some pedicle valves show minute serrations or a row of small ridges along the inner margins opposite the ears. These suggest some of the strainer devices observed in other productids. The median ridge in the anterior half of *C. inexpectata* is commonly strongly developed and undoubtedly is the counterpart to the deep groove that occurs in the median ridge of the brachial valve. These two ridges divide the anterior of this species into two halves. The same is probably true of the two other known species, but in *C. parva* the median ridge is not developed and the partition of the valves is accomplished by the median ridge of the brachial valve.

Some features of the brachial valve are variable, such as the cardinal process, the development of the median ridge, and the adductor platforms. The cardinal process varies from small, narrow, and bilobed to laterally expanded, especially at the base, and with a large quadrilobed myophore. This structure is considerably compressed dorsoventrally and is set slightly obliquely to the plane of valve junction to accommodate insertion of it under the thin, flat palintrope. On the posterior face the cardinal process is like that of other aulostegaceans in having the lateral lobes grooved. On the opposite side or ventral face the lobes are separated by a shallow depression that extends nearly to midvalve, or at least to the adductor platforms. In some specimens the two lobes are separated distally by a small, occasionally deep notch which emphasizes the bilobation. In such cases each lobe is divided by the median groove mentioned above, with the result that the cardinal process appears to be quadrilobed.

In many specimens the base of the cardinal pro-



cess is widely expanded laterally, giving the structure the appearance of a single large plate. The cardinal process is unlike the characteristic aulostegacean process in lacking the alveolus and in not having a lophidium. The lack of an elytridium is undoubtedly the reason for these absences.

The submarginal ridge of the brachial valve is one of its most important characteristics. This is usually strongly elevated on the sides but is low where it loops anteriorly and changes direction to produce the median ridge. The median portion of this ridge is most elevated and forms a flange fitting closely to the inner walls of the pedicle valve. The anterior looped portion of this ridge is commonly serrated and may thus have acted as a sieving device in feeding.

The median ridge, like most of the other characters of this interesting little genus, is variable. After the lateral submarginal ridge or flange turns medially at the anterior it extends posteromedially to unite near midvalve. This forms a knife-edge septum facing posteriorly, but the anteromedian face is a triangular groove, narrowing posteriorly, which accommodates the median ridge of the opposite valve in species which possess it.

Perhaps the most diagnostic character of this genus is the adductor platforms in the brachial valve. These make two small, elevated flat plates deeply excavated dorsally and with free edges facing ventrally and medially. These little plates range in position from horizontal to nearly vertical, viewed with the brachial valve lying on its dorsal or outer surface. This change in position is determined by the exterior curvature of the brachial valve.

*Cooperina*, according to evidence found in this study, is always attached by the pedicle umbonal region, usually by a generous portion of it. The normal position of the animal is for the adult to have the plane of its commissure at about right angles to the surface of an attachment.

The authors of *Cooperina* (Termier, Termier, and Pajaud, 1966: 332) regarded this little genus as the forerunner of the Thecideidina, which appear in the succeeding Triassic Period. The interior of the brachial valve, with its thick and elevated median ridge bisecting the shell, is obviously like that of some of the Thecideidina, especially *Davidson-*

*ella* Munier-Chalmas. In our opinion, the productid characters of this genus militate against its inclusion in the Thecideidina. These characters were outlined by us (Cooper and Grant, 1969:17) as follows: 1, presence of spines on both valves; 2, straight hinge without teeth and sockets; 3, probable pseudopunctate shell; 4, lobate cardinal process of productid type; 5, productid type of brachial ridges in the brachial valve; 6, flabellate diductors in the pedicle valve; and 7, manner of attachment to the substrate.

The productids in their evolution gradually eliminated the pseudodeltidium. It is present in Strophalosiacea but was eliminated from this superfamily to produce the Aulostegacea. A pseudodeltidium is rarely present in the Productacea (Productellidae) and it was eliminated from all of the later genera. No pseudodeltidium is present in *Cooperina*, but the pseudodeltidium is one of the most important characters of the Thecideidina. To produce a thecideid from *Cooperina* would require the redevelopment of teeth and sockets and acquisition of punctae while at the same time eliminating pseudopunctae (taleolae).

Other genera of the Cooperinidae, described by Grant (1972), exhibit forms of ptycholophous brachidia that resemble some of the Mesozoic thecideaceans and suggest that the general form of the productidine lophophore was ptycholophous. Derivation of the thecideans from some stock within the productidina remains a possibility, although the necessary changes in shell structure are great.

### *Cooperina inexpectata* Termier, Termier, and Pajaud

PLATE 210: FIGURES 1-61; PLATE 212: FIGURES 11-22

*Cooperina inexpectata* Termier, Termier, and Pajaud, 1966: 332.—Cooper and Grant, 1969:17.

Small, attached, squarish to longitudinally rectangular; sides subparallel to moderately divergent; anterior margin narrowly rounded; anterior commissure with slight fold toward brachial valve; pedicle valve strongly but unevenly convex, umbonal region flattened but anterior half subgeniculate; brachial valve flat to concave. Surface of pedicle

valve spinose, that of brachial valve with small spines in well-preserved specimens.

Pedicle valve with broad area of attachment approximating posterior half; anterior half moderately to strongly convex. Surface spinose, spines rhizoid and ornamental. Rhizoid spines long, slender, forming fringe around area of attachment and tufts on ears; ornament spines long and slender, attaining length of at least 4 mm and crudely arranged in concentric rows. Interarea moderately long, measuring 0.75 mm on shell 4mm long, flat, with anterior margin straight and extending to lateral margins to form line of contact for brachial valve. Ears small, flattened, approximately forming right angle. Umbonal cavity moderately deep, roofed by flat and delicate palintrope.

Pedicle valve interior with obscure muscle area, diductor scars appearing to occupy most of posterior half; adductors not clearly discernible but located on low short elevation in adults and old specimens; anterior half divided by low median ridge, also best defined in young or old specimens.

Brachial valve gently convex to moderately swollen in posterior half to one-third but moderately to strongly concave in anterior one-half to two-thirds. Hinge straight, articulating with or abutting straight edge of palintrope.

Brachial valve interior with elevated submarginal ridge running from each side of base of cardinal process along margins to curve narrowly at anterior and unite medially, forming elevated ridge that extends to about midvalve; submarginal ridge elevated, forming prominent wall laterally that fits into thickened lateral margins of pedicle valve. Cardinal process oblique to commissure and protruding markedly toward ventral valve, there inserted into umbonal cavity; cardinal process bilobed to trilobed, lobes moderately divergent, each lobe in old specimens also bilobed to form quadrilobed process. Base of cardinal process expanded laterally in dorsal view; grooved medially in ventral view. Ears prominent, flattened and depressed dorsally to submarginal ridge. Median ridge forming high crest almost dividing valves into two chambers, knife-edge sharp on posterodorsal edge but grooved along anterior face, groove receiving elevated ridge of pedicle valve. Adductor scars attached to two elevated platforms, or shelves, located at angle between lateral submarginal ridge

and valve floor, attachment being made on floor and to ridge; adductor platforms ranging from parallel to nearly perpendicular to valve floor, depending on curvature of shell. Well-defined productid brachial ridges in well-preserved specimens.

MEASUREMENTS (in mm).—

	length	brach- ial valve length	maximum width	hinge width	thick- ness
USNM 706e					
152637a	2.2	2	2.0	1.3	1.0
152637b	2.8	1.9	2.8	1.9	0.9
152637c	3.0	2.4	2.8	1.9	1.5
152637d	3.3	2.5	2.8	1.8	1.3
152637e	3.3	?	3.2	2.6	2.1
152637f	3.7	2.7	3.6	2.7	2.1
152637g	4.2	3.6	3.0	2.6	1.9
152637h	4.0	?	3.5	2.9	1.7
152637i	4.5	?	4.2	3.0	2.3

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member), Word Formation (China Tank, Willis Ranch, Appel Ranch members and lenses between last two), Bell Canyon Formation (Hegler Member).

LOCALITIES.—Getaway: AMNH 512, 600; USNM 728, 732. Word: USNM 732s, 737w, 741p. China Tank: USNM 706c, 706z, 726r, 733q. Willis Ranch: AMNH 505, 506; USNM 706, 706e, 723t, 723w, 724u, 735c. Appel Ranch: USNM 719z, 722t. Lenses: USNM 706b, 742b. Hegler: AMNH 635; USNM 731, 732a.

DIAGNOSIS.—Rectangular to square *Cooperina* having long curved ornament spines, a broad attachment area on the pedicle valve and strongly elevated median ridge in the brachial valve.

TYPES.—Figured hypotypes: USNM 152637d, g; 153184; 153185a, b; 153198a–n, p; 154142a, b, e, f, h; 154143a–d. Measured hypotypes: USNM 152637a–i.

DISCUSSION.—As in all attached forms, the anatomical features of *C. inexpectata* are highly variable. Such shells are so dependent on the object to which they are affixed that their shape and size are usually greatly influenced. The attachment surface of *C. inexpectata* is large and attachment is commonly reinforced by a dense fringe of rhizoid spines. The young are usually biconvex or convex-concave, depending on the surface attachment. At

this stage the plane of valve junction is parallel to the surface of attachment but as growth continues the anterior margin and the commissure gradually change direction, until in the adult, they are approximately at right angles to the attachment surface. During the time of the shifting of the angle of the commissure to the attachment surface, ornament spines appear at the margin of the growing shell.

*Cooperina inexpectata* did not have any favorite object to which it attached but used any dead shell in a sheltered position to which its larva could attach. Specimens have been seen on bryozoans, corals, pelecypods, and a great variety of dead brachiopods. The best preserved specimens are those that lodged in the living chamber of dead *Cyclacantharia*. These commonly preserve the long curved halteroid spines in best condition and completeness.

### *Cooperina parva*, new species

PLATE 208: FIGURES 13-38

Shell small, quadrate in outline, length and width about equal; sides gently rounded; anterior margin broadly rounded; hinge width slightly less than midwidth; anterior commissure without trace of folding; cicatrix of attachment large, occupying about one-third valve length; spines on pedicle valve long and slender, exact length not known, distant and scattered on surface; rhizoid spines not crowded around cicatrix.

Pedicle valve strongly convex, greatest convexity at midvalve; anterior profile broadly domed; interarea equal to about one-fifth valve length; sides thickened; ears not prominent, forming obtuse angle. Interior not showing form of muscle scars or any evidence of median septum at valve anterior.

Brachial valve of unequal convexity, posterior half gently swollen, anterior half gently concave but with anterior margin gently reflected dorsally; sides elevated into moderately high flange descending anteriorly, scarcely developed along anterior margin; anterior median ridge low and short, indistinctly defined to about midvalve; cardinal process erect, moderately stout, myophore with four small lobes. Adductor platforms elevated, slightly oblique to median line, nearly vertical, with free margins serrated.

### MEASUREMENTS (in mm).—

	length	brach- ial valve length	hinge width	maxi- mum width	thick- ness
USNM 702c					
152638a	2.3	1.5	1.4	2.4	1.2
(holotype)					
152638b	?	1.4	1.1	1.7	0.4
152638c	?	1.2	1.2	1.8	0.2
USNM 702d					
152639d	1.5	1.4	1.2?	2.0	0.3
152638e	2.0	1.5	1.8	2.3	1.2
152639f	2.0	?	1.5	1.9	0.9
152639g	?	1.4	1.0	1.5	0.3?

STRATIGRAPHIC OCCURRENCE.—Hess Formation (Taylor Ranch Member), Cathedral Mountain Formation (Wedin Member), Road Canyon Formation.

LOCALITIES.—Taylor Ranch: USNM 702d. Cathedral Mountain: USNM 702, 703a<sup>1</sup>, 721u, 723u. Wedin: USNM 700x, 723v. Road Canyon: USNM 702c.

DIAGNOSIS.—*Cooperina* with a squarish outline, scattered spines, and poor development of the median ridge in the brachial valve.

TYPES.—Holotype: USNM 152638a. Figured paratypes: USNM 154174; 154175a; 152638b, c; 152639d-g. Measured paratypes: USNM 152638b, c; 152639d-g.

COMPARISON.—The squarish outline of this species distinguishes it from the somewhat triangular outlines of *C. triangulata* and *C. subcuneata*, both new. It is smaller than *C. inexpectata* and has fewer and more scattered ornament spines irregularly arranged, and it has a much less prominent median ridge in the brachial valve.

### *Cooperina subcuneata*, new species

PLATE 209: FIGURES 38-59

Small, but about medium size for genus; outline rudely triangular with anterior wider than posterior which is considerably narrowed in most specimens. Sides rounded and converging posteriorly; anterior margin narrowly rounded. Hinge narrow, interarea moderately long, triangular, flat, and without delthyrial opening. Beak slightly incurved. Cicatrix moderately large, varying from a third to

more than half posterior surface of pedicle valve. Anchor spines delicate, forming fringe adjacent to cicatrix.

Pedicle valve most convex anterior to cicatrix, there swollen and narrowly rounded. All slopes steep. Cardinal extremities slightly to moderately acute; interior with low median ridge.

Brachial valve exterior flatly concave, umbonal region slightly swollen. Surface marked by several rows of small holes. Interior of brachial valve with thin, fairly large posterior adductor platforms. Median ridge long, high, narrowly expanded anteriorly. Cardinal process, moderately long, bilobed.

MEASUREMENTS (in mm).—

	length	brach- ial valve length	maxi- mum width	hinge width	thick- ness	height
USNM 726d						
152641a	3.0	2.8	2.5	1.9	1.2	1.4
USNM 721j						
151241a	3.5	2.7	2.7	1.7	1.4	1.5
(holotype)						
151241b	3.4	2.9	2.7	1.3	1.0	1.2

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—AMNH 501; USNM 702c, 710u, 716xa, 720d, 721j, 721s, 721t, 721x, 721z, 722e, 722v, 724c, 726d, 726e, 732j, 736x.

DIAGNOSIS.—Small subcuneate *Cooperina* with rows of pits on the brachial valve.

TYPES.—Holotype: USNM 151241a. Figured paratypes: USNM 151241b, c; 152641a; 154140; 154141. Measured paratypes: USNM 152641a, 151241b.

COMPARISON.—This species is larger than *C. parva*, new species, and less triangular and larger than *C. triangulata*, new species of the Neal Ranch Formation. It is most like *C. inexpectata* Termier, Termier, and Pajaud, but has a narrower hinge region, thinner and less robust valves, a narrower anterior expansion of the median ridge of the brachial valve, and numerous tiny pits on the exterior of the brachial valve.

DISCUSSION.—This species is generally rare, and it is difficult to find the small brachial valves in the mass of fine debris in the abundant detrital materials of interbiohermal accumulations. The specimens found in living position usually have their commissure at a low angle to the attachment sur-

face, but some are found at a fairly high angle but seldom at 90°. The most unusual feature of this species is the presence of numerous pits, arranged crudely in concentric rows on the exterior of the brachial valve. These do not seem to accord with spines of the opposite valve. They may be sites of small spines but no trace of spines was seen on any specimens, not even the best preserved ones.

### *Cooperina triangulata*, new species

PLATE 209: FIGURES 1–37

Minute, triangular in outline. Hinge very narrow; greatest shell width at anterior; lateral margins widely divergent anteriorly, indented just anterior to cardinal extremities, somewhat narrowly rounded anterolaterally; anterior margin with strong median reentrant; anterior commissure slightly folded toward brachial valve; pedicle valve deep, brachial valve nearly flat to moderately concave; rhizoid spines fine, on ears and body of shell; no ornament spines observed. Brachial valve with scattered dimples corresponding to rhizoid spines.

Pedicle valve strongly convex in lateral profile, narrowly domed in anterior profile; umbonal region narrow; umbonal and lateral slopes precipitate; anterior slope steep. Ears proportionately large flattened and protruding laterally beyond lateral margins. Interarea small, triangular, short, with median thin, translucent part over cardinal process and in position of delthyrium. Pedicle valve interior with slight thickening of floor of umbonal chamber but no median ridge or septum visible; anterior half with poorly defined median elevation.

Brachial valve in lateral profile with umbonal region gently convex to flat but anterior two-thirds broadly to moderately concave; anterior margins deflected somewhat dorsally; ears prominent, protruding laterally, approximately at right angle. Cardinal process nearly erect, quadrilobate when viewed from ventral side, bilobed to trilobed in dorsal view. Flanges along concave sides thin and strongly elevated, fitting closely inside steep sides of pedicle valve; adductor platforms small, narrow, steeply tilted. Median elevation in median half steep and high, lateral ridges forming it not meeting to make median ridge or septum, but remaining separated by deep groove of varying width.



## MEASUREMENTS (in mm).—

		brach- ial valve	hinge	maxi- mum	thick- ness	height
	length	length	width	width		
USNM 701d						
152640a	2.6	1.7	1.0?	2.6	0.8	1.4
152640b	2.7	2.1	1.1	2.6	1.0	1.3
152640c	3.1	2.2	1.2?	2.6	1.5	1.7
(holotype)						
152640d	3.2	2.6	1.4	2.7	1.6	1.8

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (bioherms in beds 9–14 of King's section and Cooper's beds 9–12).

LOCALITIES.—USNM 701, 701<sup>3</sup>, 701d, 721g.

DIAGNOSIS.—Minute, triangular *Cooperina* having a lobate anterior margin, very narrow hinge and deeply grooved median ridge in the anterior half of the brachial valve interior.

TYPES.—Holotype: USNM 152640c. Figured paratypes: USNM 154138a, b; 154139a, b; 154140d, g, e–i. Measured paratypes: USNM 152640a, b, d. Unfigured paratypes: USNM 154140a, b, f.

COMPARISON.—This species may be distinguished from the others described herein (except *C. subcuneata*, new species) by its triangular outline, lobate anterior, narrow hinge, and the deeply grooved median elevation of the brachial-valve interior, which does not terminate in a median ridge. This latter character distinguishes it from *C. subcuneata*, which is also triangular in outline.

DISCUSSION.—This little species is fairly common near the middle of the Neal Ranch Formation at its type section. Features of importance that need further explanation are the spines and the brachial valve interior.

Spines are well scattered over the surface of the pedicle valve but they consist only of rhizoid spines. They are seldom seen near the anterior margin in the few specimens attached in growth position. Most of the material available for study consists of specimens stripped of the spines. In most, the location of the spines is shown only by pits, and these do not reach the anterior margin. No ornament spines were observed on any specimens.

The features of the brachial valve interior are fairly normal for the genus, except for the median ridge. The cardinal process appears to be of the same type and fairly strongly lobed in all specimens in which it is visible. The adductor platforms are

elongate and narrow, compared to those of the other species, and are fairly widely separated. The great difference in this species, compared to the others, is in the course of the lateral flanges and submarginal ridge. The flanges are high and thin but descend in height where they approach the anterolateral margins. Here they make a narrow loop and extend posteriorly; however, they fail to unite to form a sharp median ridge or crest as in the other species.

VARIATION.—Considerable variation can be detected in the width of the hinge and the anterior. Both of these features are dependent on the object to which the shells are attached.

ECOLOGY.—The ecology of this little species is the same as that for the other members of the genus. It does not appear to have had a favorite surface for attachment but does favor crannies in dead shells.

REMARKS ON STRATIGRAPHY.—Residues from Pennsylvanian limestones have produced specimens having the form of *C. triangulata* but no interiors have been found to prove the true generic affinities of these specimens. *Leptalosia spondyliiformis* (White and St. John) from Pennsylvanian rocks of Iowa and Nebraska has the form of *Cooperina* and its interior, as indicated by specimens from Nowata, Oklahoma, has the same adductor platforms.

*Cooperina* species

Five specimens from two localities represent a possible species of *Cooperina*. Two specimens from USNM 705a (USNM 151232) are nearly square in outline, the largest measuring about 2.6 mm in length and width. It is thick-shelled, with the interior sides narrowing toward the beak, indicating a narrowing of the brachial valve. The interarea is short and narrow. The brachial valve is fairly deeply concave and has a slight dorsad wave in the anterior margin. Three specimens from USNM 728f (USNM 151247) are thick shelled and somewhat narrow at the hinge, suggesting probable identity with specimens from USNM 705a.

*Atelestegastus*, new genus

[Greek *atele* (imperfect) + *stegastos* (cover)]

Small, attached by ventral umbo and anchored by rhizoid spines; subcircular in outline; concavo-

convex in profile; anterior commissure unfolded; pedicle valve marked by scattered rhizoid and ornament spines; brachial valve with fine erect spines. Outer margin of pedicle valve broadly flattened.

Pedicle valve with palintrope and flat interarea; teeth absent; floor of umbonal chamber somewhat thickened, but adductor and diductor impressions not clearly visible.

Brachial valve with large bilobed cardinal process, each lobe divisible into two parts; shaft stout, extending anterior to posterior margin; median septum indistinct, extending anterior to midvalve; adductor impressions small; brachial ridges large, extending anteriorly from lateral margins of adductor scars and occupying most of anterior half; brachial ridges marked by row of endospines anteriorly.

TYPE-SPECIES.—*Atelestegastus marginatus*, new species.

DIAGNOSIS.—Attached aulostegaceans having broad outer rim in pedicle valve and brachial valve with reduced median septum and large brachial ridges.

COMPARISON.—This interesting genus of small attached brachiopods suggests *Cooperina* at first glance, but differs in the broad, flattened rim of the pedicle valve, absence of a prominent median septum or ridge, absence of adductor platforms, and the great development of the brachial ridges. Absence of teeth excludes it from the Strophalosiidae.

The form of the brachial valve separates this genus from any of the small aulostegids, such as *Xenosteges*.

DISCUSSION.—The most remarkable anatomical feature of this little brachiopod is the disparity in length between the pedicle and brachial valves. The brachial valve forms a lid over only a part of the pedicle valve. The outer rim of the latter is quite uncovered and suggests a trend toward the richthofeniids or teguliferinids. However, the interarea is well developed and the general morphology, except for the rim, is that of the Aulostegacea.

*Atelestegastus* contrasts quite strongly to *Cooperina* in the interior details of the brachial valve. In the latter the important features are the median ridge or ridges and the adductor platforms. In *Atelestegastus*, externally like *Cooperina*, these two characters are completely lacking.

Like other attached forms *Atelestegastus* exhibits a variety of distortions because of accidents of its situation. It apparently prefers the interior parts of dead shells where it must have been somewhat sheltered but specimens occur in which it is perched in what must have been an exposed situation.

### *Atelestegastus marginatus*, new species

PLATE 211: FIGURES 1-51

Small, subcircular, lateral and anterior margins well rounded; posterior margin umbonate, small to moderately large cicatrix of attachment; hinge straight and narrower than greatest width at midvalve; lateral and anterior margins of pedicle valve flattened, deflected, forming rim to receive against inner edge of brachial valve, pedicle valve thus forming a miniature cup. Rhizoid spines scattered with moderate density over whole surface of pedicle valve, numerous on ears and posterior margin; rhizoid spines long or short depending on surface of attachment. Ornament spines apparently few but scattered among rhizoid spines, full length not determined. Brachial valve with scattered, erect, fine, hairlike spines, true length also not known.

Pedicle valve strongly convex in lateral profile, broadly convex in anterior profile; greatest depth slightly posterior to midvalve; umbonal region swollen; all slopes steep, but anterior slope less so than lateral slopes, flattened or depressed by shallow sulcus; ears prominent, rounded on ventral side but flattened and conspicuous on dorsal side, usually forming rounded, obtuse angle. Palintrope thin, delicate, interarea flat with delthyrium visible because of extreme thinness of covering plate or when plate is broken out. Flattening of ears continued anteriorly around inner shell margin to define or surround restricted body cavity.

Pedicle valve interior with muscle scars and other details obscured or not sufficiently impressed to be visible.

Brachial valve unequal in profile, umbonal region slightly to moderately swollen, but anterior two-thirds moderately to deeply concave; anterior margin reflected dorsally to fit against inner margin of rim of pedicle valve; ears prominent, flattened; cardinal process long-shafted, stout with lateral strengthening along posterior margin; me-

dian septum much reduced; brachial ridges large, descending from sides of adductor patches directly anteriorly to make loop near anterior margin, there extending posteriorly to end near midvalve; outer margin of brachial loops low ridge laterally but marked by small endospines anteriorly. Cardinal process with prominent myophore lobes.

MEASUREMENTS (in mm).—

	length	brach- ial valve length	maxi- mum width	hinge width	thick- ness	height
USNM 701d						
150877a	3.8	?	4.1	2.9	?	1.8
150877b	3.7	2.5	4.0	2.3?	0.9	2.2
150877c	3.3	2.4	3.6	2.3	0.8	1.4
150877d	3.6	2.1	3.5	2.7	1.1	1.8
150877e	3.1	2.1	3.2	2.5?	0.8	1.6
USNM 721g						
154135c	4.7	4.2	5.0	2.3	1.3	2.3
(holotype)						

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (beds 9–14 of P. B. King).

LOCALITIES.—USNM 701, 701a<sup>3</sup>, 701c, 701d, 701h, 701k, 721g, 727e.

DIAGNOSIS.—Subcircular *Atelestegastus* with broad anterior rim on pedicle valve.

TYPES.—Holotype: USNM 154135c. Figured paratypes: USNM 150875; 150877b, f–l; 150878a, b; 154135a, b; 154136; 154137a, b. Measured paratypes: USNM 150877a–e. Unfigured paratypes: USNM 150877a, c–e.

**Family AULOSTEGIDAE Muir-Wood and Cooper, 1960**

Interarea in pedicle valve only; delthyrium usually closed by elytridium and/or lophidium. Brachial valve interior with trilobate or quadrate cardinal process with antron in young stages; brachial ridges given off horizontally.

Subfamilies: Echinosteginae Muir-Wood and Cooper, 1960; Chonosteginae Muir-Wood and Cooper, 1960; and Institellinae Muir-Wood and Cooper, 1960.

**Subfamily ECHINOSTEGINAE Muir-Wood and Cooper, 1960**

Aulostegidae with spinose pedicle valve capillate, lamellate, or costellate in some genera; brachial

valve without spines, surface dimpled, costellate or capillate; brachial valve adductor scars on platforms.

Genera in West Texas: *Echinosteges* Muir-Wood and Cooper, 1960; *Edriosteges* Muir-Wood and Cooper, 1960; *Limbella* Stehli, 1954; *Xenosteges* Muir-Wood and Cooper, 1960; and *Cactosteges*, new genus.

*Echinosteges* is generally characteristic of the Word Formation but occurs rarely in the Road Canyon and Bell Canyon formations. *Edriosteges* is confined to the Skinner Ranch, Cathedral Mountain, and Road Canyon formations. *Limbella* is commonest in the Neal Ranch Formation but ranges into the Skinner Ranch above and Gaptank below. *Xenosteges* appears first in the Lower Cathedral Mountain, is common in the Road Canyon, but less common in the Word Formation. It occurs in the Bell Canyon Formation but is rare.

**Genus *Limbella* Stehli, 1954**

*Limbella* Stehli, 1954:329.—Muir-Wood and Cooper, 1960: 107.—Williams et al., 1965:H455.

Moderately large, concavo-convex, attached by pedicle valve umbo and anchored by rhizoid spines on ears, posterior margin, and umbonal slope; anterior commissure faintly and narrowly folded; surface of pedicle valve marked by moderately long scattered ornament spines and fine costellae; brachial valve costellate but without spines. Anterior and lateral margins with flattened ventrally directed frill on both valves.

Pedicle valve usually with short and inconspicuous interarea; delthyrium open. Diductor scars flabellate, large; adductor field narrow and long, consisting of two elevated long slender inner scars and outside them a narrow dendritic but very obscure scar. Inner periphery thickened.

Brachial valve with thick, commonly exaggerated, lateral ridges extending from base of cardinal process; cardinal process deeply excavated in young but usually without antron in adults; shaft short, myophore varying from bilobed to trilobed. Lophidium long and narrow. Adductor field narrowly elliptical, consisting of inner conspicuous set of muscles and outer pair, one on each side of inner ones. Inner pair lobate; thickened, outer pair ob-

scure. Brevisseptum thin, bladelike, commonly poorly developed (or poorly preserved). Brachial ridges obscure, slightly oblique. Anterior slope marked by thick but short endospines.

TYPE-SPECIES.—*Aulosteges wolfcampensis* R. E. King (1931:95, pl. 26: figs. 1–6).

DIAGNOSIS.—Aulostegidae with costellate exterior, short interareas, no elytridium, slightly thickened muscle scars in both valves; no subperipheral rim and a frill in all adult stages.

COMPARISON.—*Limbella* is closest to *Edriosteges* and *Strophalosiella*. From the former it differs chiefly in several small details. On the exterior it is more strongly costellate than *Edriosteges*, which has been called capillate rather than costellate to distinguish the degree of development. Another feature of *Limbella* not shared by *Edriosteges* is the concentric lamellae remaining on the exterior by the continual abandonment of successive frills. The ornament spines of *Limbella* generally appear to be longer than those of *Edriosteges* especially in the younger specimens.

Inside the pedicle valve the elytridium is not developed in *Limbella* and the palintrope is usually short. The muscle field is like that of *Edriosteges*, but only the inner pair of adductor scars is well developed, and these are not elevated to the degree usual in *Edriosteges*. The outer pair of adductor scars, usually so prominent in *Edriosteges*, is usually difficult to see in *Limbella* and is never thickened as in that genus.

The interior of *Limbella* is like that of *Edriosteges* but differs in the development of the cardinal process and other features. The cardinal process in immature *Limbella* is tentlike, but with growth the antron is usually effectively filled, and generally no trace of it is left in the adult forms. The paired points on the ventral face of the cardinal process shaft, possible accessory muscle attachments in *Edriosteges*, are not developed in *Limbella*. The development of the lateral ridges of *Limbella* is in great contrast to their very modest development in *Edriosteges*. The latter genus in adult forms makes a thick subperipheral rim around the margin of the brachial valve, but such a rim is not developed in *Limbella*. Another minor difference between the two genera is the stout, long endospines on the anterior slope of the brachial valve interior in *Limbella*.

From the above it seems that the two are clearly

different genera but they are definitely closely related, perhaps *Edriosteges* having descended from *Limbella*.

*Strophalosiella* Licharew (1935) is another genus possibly closely related to *Limbella* which may, perhaps, preoccupy Stehli's genus. This point cannot be proved, however, until better specimens than that illustrated by Licharew are found and described. *Strophalosiella* is recorded from the Upper Carboniferous but no features of its interior have yet been published. The chief distinction between it and *Limbella* is the stronger costellation of the Russian shell than any seen on *Limbella*. A trace of the musculature is visible in one of Licharew's figures, which indicates no thickening of the adductor whatsoever, which is different from *Limbella* and *Edriosteges*. Although one must admit the possibility of *Limbella* being a synonym of *Strophalosiella*, the two should be maintained as separate genera until the interior details of *Strophalosiella* are made known.

DISCUSSION.—Inasmuch as details of the anatomy of *Limbella* differ from those of *Edriosteges* and other Aulostegidae, it is important to describe some of these with care. Perhaps the features, or rather lack thereof, of most importance on the exterior are the interarea and elytridium. In most specimens of *Limbella* the palintrope is short and the delthyrium open, the latter varying in width from specimen to specimen, but usually fairly narrow. A few specimens have the beak and umbo somewhat elongated, but in these the delthyrium is effectively plugged by the high, keeled lophidium. Still fewer specimens with elongated beaks have the beak curved so that it hangs over the interarea. In these a plate closes the posterior or apical end of the delthyrium. The plate, however, is concave and a feature of the interior. The posterior edge of the lophidium slides over the concave surface of this plate. It is essentially an elytridium in reverse.

Another feature of the interior of the pedicle valve worthy of notice is the dendritic outer element of the adductor field. This is usually impossible or difficult to see except in very old specimens, and may not be clear in them. The scar usually is not strongly dendritic and is not as many branched as the same scar of *Edriosteges*.

The interior of the brachial valve of *Limbella* is quite distinctive. In very young forms the cardi-



nal process is like that of other Aulostegidae, in the form of a tent. Two thin, sloping plates unite posterodorsally to bound a triangular cavity. In *Limbella*, unlike *Edriosteges* and *Echinosteges*, the cavity in the cardinal process is filled at an early age. The filling is well advanced in specimens less than 10 mm long. In most adults the cavity is filled at or before young adulthood, but some individuals failed to fill the cavity even after attaining the length and width of an adult. The variation in attainment of adult characters of the cardinal process appears to be similar in most of the genera. Specimens of small size, which would be deemed young because they are small, may have adult interior characters. Others, however, seemingly adult by virtue of their large size, may still retain many features of immaturity. These phenomena are also to be seen in *Limbella*.

The development of the cardinal process in *Limbella* is intimately linked with the development of the lateral ridges. This is a feature that constitutes an important difference between *Edriosteges* and *Limbella*. In the young the lateral ridges form on either side of the cardinal process; but as growth continues, the cavity in the cardinal process is filled from the anterior, and the proximal ends of the lateral ridges lap onto the sides of the cardinal process. This gives the lateral ridges a distinct curve, concave posteriorly. In late adulthood the cardinal process shaft appears to arise from the shelflike lateral ridge. In this form, the posterior of *Limbella* is utterly unlike that of *Edriosteges*.

The shaft of the cardinal process of *Limbella* is generally compressed and when viewed from the ventral side is divided medially by a groove. This creates a bilobed cardinal process in this view. Usually the median lobe of the myophore is deeply grooved, and this further enhances the appearance of bilobation. The myophore, however, when viewed from the posterior, is trilobed but it seldom attains the exaggerated lobation seen in *Edriosteges*.

The development of the adductor scars, especially in *L. wolfcampensis*, is worthy of note. These have the same elements noted in *Echinosteges* and *Edriosteges*, i. e., an inner set and an outer one. As in the other two genera, the inner set of adductors in *Limbella* consists of two bilobed scars, an elongate, narrowly tear-shaped inner scar and a shorter but similarly shaped scar slightly oblique and joined to the inner one at the narrow end.

These bilobed scars are the most prominent element in the muscle field. As in the other genera mentioned, these are smooth, but are much more closely pressed together. Outside of this bilobed pair is an elongate, obscure muscle patch, in some specimens showing as a series of discontinuous small scars and in others a definitely dendritic pattern, but consisting of a few lobes only. In *L. wolfcampensis* the adductor field is not greatly thickened, except for the inner pair of lobate scars, but in *L. victorioensis* the adductor field may be as strongly thickened as in *Edriosteges*.

### *Limbella costellata*, new species

PLATE 216: FIGURES 16-23

Approaching *Limbella wolfcampensis* in size, length and width nearly equal; sides gently rounded; anterior margin rounded, with wide frill in one specimen. Hinge about equal to mid-width. Surface of both valves costellate, costellae moderately strong, about 11 per 5 mm near front margin.

Pedicle valve moderately convex in lateral profile, but anterior slope steeper than umbonal slope; anterior profile moderately convex, somewhat flattened and slightly depressed by shallow, narrow sulcus. Beak small, umbonal region somewhat inflated; median region swollen; sides steep. Sulcus originating near midvalve, narrow, shallow, and inconspicuous. Ears flattened, approximately forming a right angle. Adductor field not strongly elevated. Rhizoid spines of small diameter.

Brachial valve moderately concave, deepest in umbonal region; ears flattened and prominent, separated from main concavity of valve by steepening of lateral slope; anterior somewhat flattened but with only faint evidence of fold. Dimples round, distant, and deep.

MEASUREMENTS (in mm).—

	length	sur- face length	hinge width	maxi- mum width	height	thick- ness
USNM 700g						
149086a	36.3	56.0	42.7	41.8	16.8	?
(holotype)						
149086b	33.8	48.0	36.0	39.0+	14.0	?
149086c	31.7?	51.0+	?	38.0	15.0?	11.9
USNM 702n						
154202	37.3	65.0?	40.0	35.5	21.0	14.0

**STRATIGRAPHIC OCCURRENCE.**—Gaptank Formation (approximately bed 10 of P. B. King (1937: 81), see note under USNM 700g), *Uddenites*-bearing Shale Member.

**LOCALITIES.**—Gaptank: USNM 700g, 705q. *Uddenites*: USNM 702n, 713e.

**DIAGNOSIS.**—Somewhat circular *Limbella* with strong costellae and distant deep dimples on the brachial valve.

**TYPES.**—Holotype: USNM 149086a. Figured paratypes: USNM 149086b, 154202. Measured paratypes: USNM 149086b, c. Unfigured paratype: USNM 149086c.

**COMPARISON AND DISCUSSION.**—The above description is based on 15 specimens all broken from the rock. These are thus difficult to compare with the fine and complete silicified specimens from the Neal Ranch Formation. Most of the measurements fall within the limits listed for *L. wolfcampensis* except for the length and width, which seem more nearly equal in the Gaptank species. The costellation appears to be somewhat finer and the dimples of the brachial valve deeper than in the Neal Ranch species.

Some of these specimens (USNM 149086) of *Limbella* are especially important because they are the oldest ones known and occur in a position regarded as well within the Pennsylvanian. It is interesting to record that they occur with the earliest representative and most primitive form of *Scacchinella*. They, like the latter, are thus "heralds" of the Permian. Two specimens from the *Uddenites*-bearing shale are referred to this species.

### *Limbella limbata*, new species

PLATE 217: FIGURES 5–17; PLATE 257: FIGURES 1, 2; PLATE 475: FIGURES 7–10

Large for genus, subquadrate in outline, width slightly greater than length, sides gently rounded, anterior margin broadly rounded. Pedicle valve with numerous spines, small spine bases scattered over surface; brachial valve with fine, shallow fairly numerous dimples; both valves with interrupted concentric wrinkles, and fine costellae, about 12 in 5 mm, near front margin.

Pedicle valve unevenly convex in lateral profile, maximum convexity in anterior third, anterior slope steep, posterior slope long and much less

steep than anterior one; anterior profile flatly convex on top and with precipitous sides; top of profile indented by narrow, shallow sulcus. Beak small, umbo gently convex; umbonal region broadly flattened; region just anterior to midvalve swollen; sulcus originating near midvalve, deepening anteriorly but only moderately deep at front of some specimens, scarcely visible and broad in others. Interarea short, nearly flat; muscle field with adductors not strongly thickened. Broad anterior frill present in well-preserved specimens.

Brachial valve gently concave, deepest in anterolateral parts; umbo broad, shallow, depressed; median line of ventrally sulcate specimens elevated to form low fold varying from distinct to non-existent. Ears flattened, not strongly demarcated. Lateral ridges curved, strong, adductor field only moderately thickened even in large shells.

Brachial valve interior with large cardinal process but nonthickened adductor field. Lateral ridges thick and solid.

### MEASUREMENTS (in mm).—

	length	surface length	maxi- mum width	height	thick- ness	frill length
USNM 714t						
149101a	31.6	56.0	39.7	16.6	13.8	?
140101b	40.0	61.0	39.3	20.0	16.0	?
149101c	31.9	50.0	38.3	12.6	?	?
149101d	34.7	54.0	42.7	15.8	?	?
149101e	31.0?	45.0?	33.5	16.0	?	10.5
149101f	32.8	46.0	32.4	12.7	?	?
149101g	28.2	36.0	35.0	7.8	?	?
USNM 722-1						
154208a	30.0	44.0	38.7	15.5	?	10.6
(holotype)						
154208b	33.0	50.0	34.0	17.0	?	10.0
154208c	34.0	?	39.0	?	?	?

**STRATIGRAPHIC OCCURRENCE.**—Cibolo Formation, Skinner Ranch Formation (Dugout Mountain, Decie Ranch, Poplar Tank, and Sullivan Peak members), Skinner Ranch (base or top).

**LOCALITIES.**—Cibolo: USNM 738c, 738q. Dugout Mountain: USNM 732e. Decie Ranch: USNM 707a, 714t, 715a. Poplar Tank: USNM 707ha, 708e, 741k. Sullivan Peak: USNM 705o, 707, 707b, 707d, 707g, 707x, 709-1, 713m, 715u, 722k, 722-1, 727a, 733j, 739g. Skinner Ranch (base): USNM 705a, 705n, 707w, 708q, 711d, 712p, 715n, 716p, 739-1. Skinner Ranch (top): USNM 710r, 722m, 723-1, 723s, 727f, 729-1.

**DIAGNOSIS.**—Large *Limbella* with numerous

spines on pedicle valve and many somewhat crowded dimples on the brachial valve, strongly convex in lateral profile and with deep pedicle valve.

**TYPES.**—Holotype: USNM 154208a. Figured paratypes: USNM 149075; 153922a, b; 154208b, c, e; 154111. Measured paratypes: USNM 149101a–g; 154208b, c. Unfigured paratypes: USNM 154208d.

**COMPARISON.**—Most of the specimens of this species, except the types, are not silicified, making direct comparison with silicified specimens difficult. Nevertheless, the species is closest to *L. wolfcampensis* but is often larger and always deeper than the Neal Ranch species. In its often wide shells this species also suggests *L. victorioensis* Stehli but is deeper, and the frill is not so wide as in the Sierra Diablo species. The lateral profile of *L. limbata* is different from that of both *L. victorioensis* and *wolfcampensis*.

### *Limbella victorioensis* Stehli

PLATE 215: FIGURES 4–27; PLATE 216: FIGURES 1–10

*Limbella victorioensis* Stehli, 1954:329, pl. 23: figs. 8–12.

This species is uncommon in the Sierra Diablo, and it is difficult to obtain good specimens. None was found with both valves articulated, suggesting a type of occurrence different from that of *L. wolfcampensis* (R. E. King) from the Glass Mountains where many specimens were taken with both valves in contact. The two species are quite different when numerous specimens can be compared. *L. wolfcampensis*, however, has occasional individuals that outstrip the Sierra Diablo species in size, but generally the Sierra Diablo species appears to be larger and more robust.

The interiors of the two species also are different. The musculature of *L. wolfcampensis* is much more lightly impressed inside the pedicle valve than the other species and the brachial valves of the Sierra Diablo species has a stronger development of the adductor callosities. Furthermore, the cardinal process of the latter is generally more robust, but it is difficult to make a comparison, except in a broad way. *Limbella victorioensis* shows retardation and acceleration of growth of these structures in the same manner as seen in *Echinosteges*.

There is no reason to believe that *L. victorioensis* lived in a manner different from that of *L. wolfcampensis*.

*campensis*, which has been found in its actual living position.

**MEASUREMENTS** (in mm).—From USNM 728f, specimens 152648a and b, respectively: length 28.0, 31.2; brachial valve length 27.5, 27.9; maximum width 36.7, 26.8; hinge width 31.8, 31.3; height 16.7, 18.4; frill length 12.5, 13.2; surface length 45.0?, 50.0.

**STRATIGRAPHIC OCCURRENCE.**—Bone Spring Formation.

**LOCALITIES.**—AMNH 629; USNM 725c, 728e, 728f, 728h, 742, 746.

**DIAGNOSIS.**—Large, wide-frilled *Limbella*.

**TYPES.**—Lectotype: AMNH 27310/1:1. Figured paratypes: AMNH 27310/1:2–4. Figured hypotypes: USNM 152648a–c, 154200a–i. Measured hypotypes: USNM 152648a, b.

**DISCUSSION.**—The fine costellae of *L. victorioensis* are difficult to see, perhaps because of preservation, but the few specimens revealing costellae show them to be very similar to those of *L. wolfcampensis*. Like those of the latter they are low and broad, rather crowded, and number about 14 in 5 mm at the front of a large brachial valve, slightly more than in *L. wolfcampensis*. The Sierra Diablo species is also marked by the same thin, wavy, concentric lamellae that are abundant on the surface of *L. wolfcampensis*, but in most specimens they are not so abundant as in the Glass Mountains species. The frill of the Sierra Diablo species, when well-formed, appears to be wider than that of *L. wolfcampensis* but, again, this is a matter of a few specimens showing this condition. Anterior costation appears to be more prevalent in the Sierra Diablo species, and with somewhat stronger costae. An interesting feature of the anterior frill is its costation which corresponds to the anterior row of spines, each spine above or resting in the space between costae. Evidently the spines are responsible in part for the wrinkling of the frill.

### *Limbella wolfcampensis* (R. E. King)

PLATE 213: FIGURES 1–29; PLATE 214: FIGURES 1–21; PLATE 215: FIGURES 1–3; PLATE 216: FIGURES 11–13, 15

*Aulosteges wolfcampensis* King, 1931:95, pl. 25: figs. 1–6.—Muir-Wood and Cooper, 1960:107, pl. 131: figs. 6–16.

Medium size, thin, subrectangular in outline; widest at about midvalve; sides gently rounded;

anterior margin broadly rounded. Hinge generally narrower than midwidth. Surface costellate, subcostate, and spinose.

Pedicle valve somewhat narrowly and evenly convex in lateral profile; moderately and broadly convex in anterior profile; beak small, incurved; umbo swollen, merging with greatly swollen median region; lateral and anterior slopes precipitate; sulcus narrow, shallow, originating posterior to midvalve and extending to anterior margin. Ornament spines distantly scattered, gently curved, moderately long (10 mm) and tapering gently. Rhizoid spines thickest and largest on ears, becoming more slender and smaller medially; rhizoid spines extending anterolaterally onto posterior part of frill. Entire surface marked by fine broad radial costellae, 7 to 10 in 5 mm at front of pedicle valve of adults, radial costellae and obscure interrupted costae, the latter originating anterior to base of ornament spine. Frill extending obliquely ventrad, moderately long (15 mm).

Pedicle valve interior with short, curved interarea, delthyrium narrow, open; umbonal chamber filled by muscle field, diductor scars large and flabellate; adductor field long and slender, median

scars strongly elevated, surface smooth but long, narrow, and bilobed. Inner lobe long, lateral lobe short. Outer adductor scars obscure, difficult to see, faintly dendritic. Lateral walls of umbonal chamber covered by mat of small endospines.

Brachial valve interior with prominent, frequently shelflike lateral ridges hanging over adductor field; lateral ridges uniting with thin, usually short ear baffle bounding inner part of ear; cardinal process shaft united with brachial ridges. Cardinal process of young, open, tentlike, thickening and filling with age; adult cardinal process usually narrow, ventrad face bilobed, but myophore trilobed. Adductor field consisting of paired scars, each scar divisible into three scars. Inner pair of scars bilobed, smooth and strongly elevated; outer scars depressed, difficult to see and obscurely dendritic. Areas on each side of muscle field minutely endospinose. Brachial ridges faintly impressed, commonly not seen, somewhat posteriorly located. Brevisseptum varying from thin, threadlike ridge to thin, bladelike septum, highest at anterior extremity and usually extending slightly anterior to midvalve. Anterior slope marked by large, stout, conical endospines.

MEASUREMENTS (in mm).—All hypotypes.

		<i>brachial</i>						
	<i>length</i>	<i>valve length</i>	<i>surface length</i>	<i>hinge width</i>	<i>maximum width</i>	<i>height</i>	<i>thickness</i>	<i>frill length</i>
USNM 701k								
149052a	33.2	24.4	52.0	39.8	41.2	19.6	10.8	6.0
149052b	31.3	21.7	41.0	30.6	39.2	14.0	7.4	8.0
149052c	26.5	18.7	40.0	32.7	34.6	13.1	0.3	3.0
149052d	18.0	15.9	26.0	15.9	23.3	7.5	5.3	?
149052e	9.0	8.5	13.5	9.1	10.8	4.8	2.8	?
149052f	35.3	29.4	53.0?	44.0?	48.8	17.8?	10.0	6.0
USNM 701h								
149049a	37.7	?	56.0	39.0	47.3+	18.5	?	5.0
149049b	35.9	26.0	63.0	39.1	42.1	17.0	10.4	8.5
149049c	32.4	23.0	?	36.5	40.6	15.5	11.1	4.5
149049d	29.4	21.6	44.0	30.0?	34.1	15.3	8.5	5.0
149049e	25.0	19.0	43.0	26.8	30.6	15.0	10.2	?
149049f	19.3	18.6	25.0	15.5	18.8	7.0	3.1	?
149049g	13.2	12.0	15.0	11.9	14.4	3.3	3.0	?
149049h	10.1	7.8	11.5	5.9	8.6	3.3	2.4	?
149049i	5.6	5.2	7.0	5.6	6.9	2.7	1.9	?
USNM 701								
149063	45.6	31.2	68.0	41.7?	59.0	23.0	15.0	11.0
USNM 701c								
149053a	38.0	26.7	61.0	36.0	44.4	26.6	16.4	?
149053b	37.4	28.9	62.0	41.7	44.3	20.2	11.8	6.0



**STRATIGRAPHIC OCCURRENCE.**—Gaptank Formation (*Uddenites*-bearing Shale Member), Neal Ranch Formation, Lenox Hills Formation.

**LOCALITIES.**—*Uddenites*: USNM 701v, 703x. Neal Ranch: USNM 701, 701a, 701a<sup>1</sup>, 701a<sup>3</sup>, 701c, 701d, 701g, 701h, 701k, 701-l, 706x, 727e, 742c. Lenox Hills: USNM 704q, 705, 705k, 705m, 705s, 706g, 707j, 707m, 707z, 709t, 710w, 713q, 715, 715b, 716r, 737u.

**DIAGNOSIS.**—Large, subquadrate *Limbella* with rough, irregularly scaly surface.

**TYPES.**—Lectotype (herein designated): YPM 11847a. Figured paratypes: YPM 11839, 11847b, 11849. Figured hypotypes: USNM 124120a, c, d, g; 149049b, c; 149052d; 149053a; 149061a-j; 154201; 154203; 154204; 154205; 154206; 154207; 154199. Measured hypotypes: see list.

**TYPE-SPECIMENS.**—R. E. King's cotypes consist of four lots of specimens, three of them at Yale and one at Austin. Lot YPM 11849 consists of two specimens from locality 193 (R. E. King 1931, pl. 26: fig. 1). The larger of the two specimens is decorticated, both sides have been broken and the hinge and most of the beak are buried. It is a pedicle valve only but shows the strong convexity and the shallow sulcus extending from the umbo to the anterior margin. The anterior margin is reflected fairly strongly in an anteroventral direction. The umbonal and visceral regions are strongly wrinkled. The second specimen in this lot is a fragment only of a young individual showing the longitudinal median region with a moderately deep sulcus.

YPM 11839 from locality 88S (R. E. King 1931, pl. 26: figs. 5a, b) is another fragmentary pedicle valve with lateral margins broken away and only part of the hinge preserved. Part of the exterior surface preserves strong costellae on the umbonal and visceral regions. The specimen is strongly convex and strongly geniculated (an angle of 83°). King's idea that this is a triangular species evidently was derived from these broken pedicle valves.

YPM 11847 consists of two specimens, one (R. E. King 1931, pl. 26: fig. 2) showing the interior of the brachial valve and the other (R. E. King 1931, pl. 26: fig. 3) a partial interior and partial impression of the exterior, the latter showing well the impressions of the costellae and fairly well the rectangular form, although the ears are broken off both sides. The specimen showing the interior has

the cardinal process fairly well preserved, and the lateral ridges are strong. The muscle area is clear but the median septum shows as only a slight line. Not one of the Peabody specimens is complete, and the three lots are hardly adequate to define a species.

The same is true of the Texas specimens. T10185 consists of two specimens from locality 93. One of these, a fragment of the brachial valve interior, shows the cardinal process and muscle scars. The other specimen in this lot is an exfoliated pedicle valve, larger and somewhat less strongly geniculated than the other pedicle valves of the cotype lots.

Although none of these cotypes is suitable to characterize the species, a type must be selected from them if the species name is to survive. Inasmuch as a genus has been based on this species, it seems reasonable to put the species on as sound a basis as possible. Two stratigraphic levels are represented by these cotypes. One specimen (YPM 11839) comes from the *Uddenites*-bearing Shale Member. This specimen, which preserves its shape and ornamentation better than any of the others, is eliminated from consideration because many of the fine silicified specimens illustrated herein come from approximately King's locality 93, the location for several other cotypes. Specimen lot YPM 11849 is also eliminated from consideration. This lot is from Dugout Mountain and comes from the Lenox Hills Formation, a level far above the bed nine (of P. B. King) of the Neal Ranch Formation from which the remainder of the cotypes are said to have come. Neither of the cotypes belonging to the University of Texas shows the outline well, nor does the pedicle valve have the ornament well preserved. By elimination we are left with the two brachial valves of lot 11847, and of these the specimen marked 11847a is the better. We select it as the type of the species.

The lectotype is an imperfect brachial valve but it shows well the curved, strong brachial ridges, the subdued adductor field, and the thick endospines on the anterior slope. These are all features of the brachial valves of silicified specimens from USNM 701c, which is approximately King's locality 93. The list furnished by R. E. King from "bed 9" at locality 93 is, as King states, probably float from "The next few higher beds on the side of the arroyo northeast of Wolfcamp" (R. E. King 1931:134). The limbellas were probably derived from P. B.

King bed 12 (=Cooper bed 9), where the genus is abundant.

COMPARISON.—Exterior and interior, details separate *Limbella victorioensis* Stehli from *L. wolfcampensis* King. Fine details of the exterior of the Sierra Diablo shell are not well preserved, but Stehli gave the main difference between the two species to be the lesser development of the costellae in *L. victorioensis* than in the Glass Mountains species. Other exterior differences between the two species appear to be the more recumbent nature of the ornament spines of *L. victorioensis*, the more prominent pustules at the base of the spines, and the narrower, shorter costae anterior to the pustules. The brachial valve of the Sierra Diablo shell is flatter than that of *L. wolfcampensis*.

Inside the pedicle valve of *L. victorioensis* an oblique ridge is developed inside the ear, whereas in the Glass Mountains species the ear is flattened and partly overhangs the umbonal chamber. The ear of *L. wolfcampensis* is more strongly developed than that of the other species. Inside the brachial valve of *L. victorioensis* the brachial ridges extend directly laterally and are not curved. Furthermore, the adductors muscles are attached to thick platforms, as in *Edriosteges*. The endospines of the Sierra Diablo shell are much thicker than those of *L. wolfcampensis*.

DISCUSSION.—The localities USNM 701c, 701h and 701k are all bioherms along the same strike but the specimens from each of these localities vary slightly. Those from the first place are more robust than the others. The bioherms represent assemblages that once lived together rather than being washed into an environment. The variations shown by these specimens probably resulted from crowding together or contending with other species for space.

Specimens of *Limbella*, few in number, were found in the *Uddenites*-bearing Shale Member of the Gaptank Formation just under the thick limestone identified as lower "Wolfcamp" by P. B. King. These specimens are not silicified and are difficult to identify. Their characters however, suggest to us that they are the same species as *L. wolfcampensis*.

A feature characteristic of this species worthy of mention is the concentric lamellae appearing on the venter and slopes. This consists of numerous and crowded layers of shell which represent remnants of the frills produced by contraction and advance of the mantle at various stages in the growth.

## *Limbella* species 1

PLATE 216: FIGURE 14

Small to medium for genus, length and width nearly equal; outline subquadrate; sides gently rounded, anterior margin rounded and medially indented. Interarea short, about orthocline. Surface marked by fine, low, broad, and crowded costellae. Ornament spines short, scattered. Rhizoid spines long and slender, bunched on ears.

Pedicle valve unevenly convex in lateral profile, greatest convexity just anterior to midvalve, posterior slope flattened, anterior slope steep. Anterior profile a broad, flat-topped dome with slight median depression. Beak short; umbonal region usually somewhat swollen. Sulcus usually prominent, shallow and inconspicuous on posterior slope, fairly strong and moderately deep on anterior half. Flanks bounding sulcus moderately swollen.

Brachial valve with maximum concavity in umbonal region, median region marked by broad, low fold originating just posterior to midvalve and extending to margin. Flanks moderately deep, anterior margins strongly deflected.

Interior not seen.

MEASUREMENTS (in mm): From locality USNM 713x, specimen 152647, and from 702f, 149070a, respectively: length 28.5, 28.2; brachial valve length (?), 23.6; maximum width 30.9, 30.8; hinge width 28.6\*, 27.6; thickness (?), 7.3; height 10.7, 13.5.

STRATIGRAPHIC OCCURRENCE.—Hess Formation (Taylor Ranch Member), Skinner Ranch Formation (top).

LOCALITIES.—Hess: USNM 702d, 702e, 702f, 702m, 713x, 716n, 716o. Skinner Ranch (top): 705r.

DIAGNOSIS.—Subquadrate *Limbella* with maximum thickness and convexity anterior to midvalve and with a strong median sulcus.

TYPE.—Figured specimen: USNM 152647.

DISCUSSION AND COMPARISON.—This species is uncommon and difficult to obtain in a satisfactory state for description. It is also difficult to prepare specimens because they occur in a very siliceous matrix and cannot be cleanly etched. Had good specimens been obtainable, we would have established it as a species. It is readily distinguishable from the other limbellas by its medium size, the strong sulcus, and the even, broad costellae.

Some uncertainty exists in the generic designation of this species because it has the appearance of

*Edriosteges* and apparently occurs with a species of that genus. The usual fairly strong development of the costellae on the pedicle valve, a feature rare in *Edriosteges*, determined the assignment to *Limbella*. Some decorticated specimens of *Limbella* from the Skinner Ranch Formation have the general form and size of the Taylor Ranch specimens but it is not possible to be sure of that assignment.

### Genus *Edriosteges* Muir-Wood and Cooper, 1960

*Edriosteges* Muir-Wood and Cooper, 1960:103.

Generally large, usually quadrate to subpentagonal, concavo-convex with slight and narrow dorsal fold in anterior commissure, pedicle valve with long rhizoid spines on ears, posterior margin, and posterolateral umbonal slopes; body of shell covered by distant, short, curved, recumbent ornament spines. Brachial valve with concentric wrinkles and fine radial capillae.

Pedicle valve interior with large flabellate adductor scars, elongate and elevated adductor field occupied by anterior elongated scars and posterior shorter scars. Elytridium short and usually poorly developed.

Brachial valve with cardinal process and lophidium as in *Echinosteges*; adductor scars strongly dendritic, not on elevated platforms; brevisseptum small and low brachial ridges horizontal, prominent.

**TYPES-SPECIES.**—*Edriosteges multispinosus* Muir-Wood and Cooper (1960:104, pl. 17: figs. 1–10).

**DIAGNOSIS.**—Concavo-convex, nontuberculate Echinosteginae having a capillate brachial valve, slight development of the elytridium and adductor scars only slightly elevated.

**COMPARISON.**—In its general form and other exterior details *Edriosteges* most closely resembles *Echinosteges* and *Limbella*. The differences between these genera consist of numerous small but nevertheless persistent and cumulative characters. *Echinosteges* differs from *Edriosteges* in exterior details in having both valves strongly tuberculate, in having a greater development of the palintrope of the pedicle valve, and a consequent greater development of the elytridium. The brachial valve of *Echinosteges* is usually more nearly flat or anteriorly gently concave rather than strongly concave as in *Edriosteges*. It is also faintly to moderately strongly capillate.

Internally, the pedicle valves of the two genera are essentially the same but differences can be de-

tected in the brachial valves. In *Edriosteges* the adductor muscle scars are not located on elevated and excavated platforms as they are in *Echinosteges* and the brachial ridges of *Edriosteges* are much more strongly developed than in the other genus. The cardinal processes of the two are essentially the same with the exception that the antron of *Edriosteges* tends to be more completely obliterated than in *Echinosteges*. This is hardly a generic character but is worthy of note.

The fairly strong capillation of both valves of *Limbella* and the longer, stronger, and more distant recumbent spines on the body of the pedicle valve distinguish this genus externally from both of the others. The palintrope of the pedicle valve of *Limbella* is shorter than that of the other two genera and the cardinal process and adductor field are also very different. Consequently, *Limbella* in reasonably well-preserved specimens is readily distinguishable from *Edriosteges* and *Echinosteges*.

### *Edriosteges beedei* (R. E. King)

PLATE 218: FIGURES 12–20; PLATE 223: FIGURES 19–22

*Aulosteges beedei* King, 1931:92, pl. 25: figs. 12, 13 [not 14 = *Echinosteges* and not 15 = young of *Echinosteges tuberculatus*].

Types consist of four specimens marked cotypes: YPM 11876a and 11876b, T10690, and T11045. The first is a flattish specimen with imperfect margin, nearly square, length and width nearly 20 mm. The second is more elongated than the first and with much of the left side missing. The third has two valves, and the beak is longer and more attenuated than that of the Yale specimens. This type and the Yale specimens are from the Leonard Formation (loc. 123), but the fourth, cotype T11045, is from the Word Formation and is clearly an interior of *Echinosteges tuberculatus* (King) and not related to *A. beedei*. We select cotype YPM 11876a as type of the species.

As thus restricted the name becomes useful for a flattish *Edriosteges* that occurs in the Cathedral Mountain Formation. The lectotype is obviously an immature specimen. An adult has the following characters: it is elongate, rectangular in outline, and with a moderately long frill restricted to the pedicle valve. The lateral profile is moderately convex but in anterior profile it is somewhat narrowly domed. The interarea is long and has a long narrow elytridium. Ornament spines are fairly evenly but distantly scattered over the surface and, as shown by the lectotype, are short and stout. The

brachial valve is broadly and moderately concave and has a large lophidium.

MEASUREMENTS (in mm).—From locality USNM 702, specimen 149120 (hypotype): length with frill 47.0, brachial valve length 32.0, width without frill 29.9, interarea length 10.0, height 13.2, thickness 8.0, length of frill 8.4.

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITIES.—R. E. King 123, USNM 702.

DIAGNOSIS.—Elongate and somewhat flattened *Edriosteges* with scattered, short, stout ornament spines.

TYPES.—Lectotype: YPM 11876a. Paratypes: YPM 11876b, T10690. Figured hypotypes: USNM 149119, 149120.

COMPARISON AND DISCUSSION.—This species is a smaller and less robust form than *E. multispinosus* Muir-Wood and Cooper and has a shorter frill and narrower outline. One specimen (USNM 149119) illustrates a type of injury common in attached forms when one side impinges against a resistant object which prevents or distorts growth on one side.

*Edriosteges compactus*, new species

PLATE 223: FIGURES 1–16

Small for genus, subcircular to square in outline; sides nearly straight; anterior margin gently rounded; anterolateral extremities narrowly

rounded. Shell thick. Hinge nearly as wide as maximum width just anterior to midvalve. Ears nearly at right angles. Surface of pedicle valve concentrically wrinkled and with distant short spines (about 7 mm) with small, slightly swollen bases. Rhizoid spines on ears stout. Anterior marginal frill short.

Pedicle valve moderately and evenly convex in lateral profile, maximum curvature at or slightly anterior to midvalve; anterior profile somewhat narrowly domed but depressed medially by shallow sulcus. Umbonal and median regions inflated, beak small and inconspicuous. Lateral and anterior slopes precipitous. Sulcus moderately wide and shallow, originating just posterior to midvalve and extending to anterior margin. Interarea usually short but variable; elytridium usually small.

Brachial valve moderately concave, greatest concavity anterior to midvalve; posterior third nearly flat. Surface wrinkled and obscurely dimpled.

Pedicle valve interior having greatly thickened adductor field with individual scars like those of *E. multispinosus*. Brachial valve interior with prominent lateral ridges and long plane area posterior to them. Subperipheral rim thick and well-developed. Adductor field enormously thickened but scars similar to those of *E. multispinosus*. Cardinal process thick-shafted and elaborate but with antron not closed; ventral face of cardinal process usually bilobed, myophore bilobed or trilobed, commonly exaggerated. Brachial ridges rounded, usually fairly well impressed. Brevisseptum variously developed.

MEASUREMENTS (in mm).—

		brachial						
	length	valve length	surface length	hinge width	maximum width	height	thickness	frill length
USNM 721t								
152651a	30.0	22.3	50.0	24.3	28.5	18.0	11.2	4.3+
(holotype)								
152651b	28.6	23.2	44.0	23.0	31.4	12.4	8.5	?
152651c	28.7	22.0	48.0	25.7	33.3	15.5	10.0	?
152651d	28.8	20.6	41.0	18.3	27.7	13.4	9.2	2.6+
152651e	23.8	19.9	30.0	19.3	21.6	8.8	6.0	?
USNM 709c								
149139e	31.0	21.4	45.0	23.6	32.8	17.6	11.5	7.5
149139f	31.7	24.0	52.0	28.0	38.7	15.0	14.3	?
149139g	26.0	20.4	36.0	20.0	23.7	10.4	6.4	?
149139h	20.1	16.7	25.0	20.0	24.2	7.5	6.8	?
149139i	16.8	14.9	20.0	14.5	17.7	5.5	4.5	?
149139j	12.3	?	16.5	10.0	13.0	4.4	?	?
USNM 710u								
149140a	31.1	25.1	48.0	24.0	31.0	15.8	10.0	?
149140b	32.8	20.5	?	28.7	35.0	17.5	?	?
149140c	?	25.4	?	22.0	27.0	?	?	?
149140d	?	25.4	?	24.6	25.7?	?	?	?



STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 709c, 710u, 716z, 721j, 721t, 721y, 722e, 722f, 723x, 724a, 724d, 726d, 726e, 726f.

DIAGNOSIS.—Small, quadrate, thick-shelled *Edriostege*s with greatly exaggerated interior details.

TYPES.—Holotype: USNM 152651a. Figured paratypes: USNM 149137e, 149140c, 152651c. Measured paratypes: USNM 149139e–j, 149140a–d, 152651b–e. Unfigured paratypes: USNM 149137a–d; 149140a, b; 152651b, d.

COMPARISON.—This species differs from *E. beedei* (R. E. King) in its smaller size and greater convexity. It differs from *E. multispinosus* Muir-Wood and Cooper in its smaller size and subcircular to nearly square outline, moderate concavity of the brachial valve, and the exaggerated details of the interior. Many specimens of *E. multispinosus* attain greatly thickened muscle fields and cardinal process but the degree of thickening attained by *E. compactus* is usually not reached by the other species at the same length as in the Road Canyon form. Another feature characteristic of *E. compactus* is the great thickening of the cardinal process, without, at the same time, obliterating the antron. In nearly all the specimens of the brachial valve in the collection the antron is open, usually to a considerable degree.

### *Edriostege multispinosus* Muir-Wood and Cooper

PLATE 218: FIGURES 1–11; PLATE 219: FIGURES 1–27; PLATE 220: FIGURES 1–32; PLATE 221: FIGURES 1–23; PLATE 222: FIGURES 6–13; PLATE 223: FIGURES 17, 18

*Aulostege medlicottianus*, R. E. King (not Waagen), 1931:93, pl. 26: figs. 8, 9.

*Edriostege multispinosus* Muir-Wood and Cooper, 1960:104, pl. 17: figs. 1–10.

Variable, strongly concavo-convex, subcircular to subtriangular in outline; sides and anterior margin gently rounded. Hinge equal to or less than shell-width. Greatest width at or anterior to midvalve. Ears prominent, forming obtuse angles in pedicle valve.

Pedicle valve strongly and fairly evenly convex in lateral profile; strongly domed in anterior profile but gently and narrowly sulcate medially. Umbonal region moderately to strongly convex; median region swollen; lateral and anterior slopes steep;

umbonal slopes steep. Sulcus shallow, occupying the anterior two-thirds. Anterior margin in old shells recurved ventrad to form smooth, capillate, or irregularly wrinkled frill from 5 to 15 mm long.

Pedicle valve surface spinose, body spines recumbent, slender, curved ventrad, and ranging in length from few millimeters to more than 12 mm. Spine bases only slightly swollen. Rhizoid spines in most individuals confined to ears and posterior margins, densely matted, long and ramifying, rare on umbonal slopes but occasionally appearing on frill. Palintrope generally short and wide; delthyrium narrow, usually occupied by short, irregular elytridium commonly poorly developed, but in some specimens flared and expanded anteriorly to form socket for lophidium. Ornament, besides spines, consisting of irregular, obscure, discontinuous costae and fine capillae covering entire exterior especially near anterior margin.

Pedicle valve interior with deep umbonal chamber occupied by elongate and swollen adductor field separating broadly flabellate diductor scars; adductor scars consisting of anterior pair, an inside elongate scar with one or two oblique lateral lobes on outside, and two strongly dendritic, elongate scars lying obliquely behind anterior pair.

Brachial valve varying from fairly deeply concave in young adults to gently concave in old individuals; exterior marked by irregular concentric wrinkles especially near ears, entire surface covered by fine, usually somewhat obscure capillae. Interior with variable cardinal process varying from deeply excavate tentlike structure at right angles to valve surface to strongly tri- to quadrilobate and solid; myophore usually strongly trilobate. Adductor scars thickened but not forming elevated platform, interior pair lobate, consisting of long inner scar running length of field and shorter oblique anterolateral lobe; outer scar also elongate but lying obliquely outside inner scar and strongly dendritic; brevisseptum reaching slightly anterior to midvalve, bladelike and most elevated anteriorly, extending posteriorly to about midway between adductor scars. Lateral ridge varying from absent to strong and extending laterally from base of cardinal process to ear, there in some old specimens, meeting moderately thick, subperipheral rim; anterior slope marked by fine, scattered endospines. Brachial ridges well developed only in old specimens.

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	maximum width	height	thickness	frill length
USNM 703a								
123906a	46.1	35.3	73.0	43.8	44.7	22.0	14.8	?
(holotype)								
123906b	36.0	30.0	57.0	41.0	43.7	22.0	13.5	8.5
149116a	52.2	?	78.0	42.0	64.6	27.0	?	?
149116b	40.5	32.8	58.0	38.7	45.5	20.6	13.2	?
149116c	31.7	25.9	45.0	31.0+	40.2	14.1	7.7	?
149116d	30.2	25.8	41.0	25.4	33.4	11.6	8.0	?
149116e	19.1	17.3	27.0	20.0	24.8	8.2	5.6	?
149116f	12.5	10.5	14.0	11.0	12.8	3.7	1.8	?
149116g	7.3	?	8.0	8.0	9.3	2.0	?	?
149116h	18.7	14.5	26.0	12.9	21.6	7.1	5.4	?
149116i	4.6	3.5?	5.0	4.0	5.6	1.6	1.2?	?
USNM 702c								
149122a	47.6	39.2	75.0	45.5	47.2	23.4	10.0?	?
149122b	41.6	28.4	58.0?	35.3	46.7	22.1	17.0	12.0
149122c	45.5	30.0*	66.0?	33.4	56.8	22.9	?	10.0
149122d	46.7	24.3	56.0?	30.8	42.2+	19.8	10.3	15.0
USNM 703a <sup>1</sup>								
152650	51.8	39.7	68.0	42.7	52.6	20.0	13.3	?
USNM 703b								
149117	25.0	20.5	34.0	29.2	31.2	10.0	5.9	?

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain and Road Canyon formations.

LOCALITIES.—Cathedral Mountain: AMNH 500; USNM 702, 702a, 702b, 702inst., 702 low, 702un, 703a<sup>1</sup>, 703b, 703bs, 708c, 711q, 714w, 721u, 723u, 726o, 726u, 726y, 732u. Road Canyon: AMNH 501, 503, 507; USNM 702c, 703a, 703c, 703d, 707e, 716x, 719x, 720d, 721j, 721o, 721r, 721s, 721w, 721x, 721y, 721z, 722v, 724b, 724c, 724j, 726d, 726z, 732m, 734j, 735b.

DIAGNOSIS.—Strongly convex *Edriosteges* usually subquadrate outline and scattered strong spines over the pedicle valve.

TYPES.—Holotype: USNM 123906a. Figured paratypes: USNM 123906b, c; 123907. Figured hypotypes: USNM 149115a-c; 149121; 149122d; 154183b, d, f, g, i-k, m, n, p-w; 154184a-h, l, m, p, q; 154185a-f; 154187; 154188a, b; 154189a-c. Measured hypotypes: USNM 123906b, 149116a-i, 149117, 149122a-d, 152650.

DISCUSSION.—Like *Echinosteges*, *Edriosteges* is variable; the variations in the two genera are quite similar but some differences can be noted. It is therefore pertinent to discuss in some detail the anatomical features of *E. multispinosus* so they may

be compare with those of *Echinosteges*, as detailed under that genus.

EXTERIOR.—In general the young are wider than long, nearly plano-convex and anchored in the usual fashion. Growth additions are greater anteriorly than laterally, with the result that the depth of the pedicle valve increases. This makes for increasing height with growth and a strongly convex adult. Naturally some specimens reach maximum convexity more quickly than others and a few remain only moderately convex throughout life. These modifications may be accounted for by the congeniality of living conditions in the particular site occupied by an individual. Attainment of old adult characters before maximum length is reached and retention of juvenile features after maximum length has been achieved can be observed in numerous specimens. In spite of this the characteristic form of the adult is strongly convex.

The frill is variably developed, from absent to a length of 15 mm. This feature may appear in shells before attainment of maximum length for the species and is a good sign of maturity. The spines too, are not uniformly developed. In some specimens they are somewhat more crowded than in

others, and a few appear to have smaller spines over the entire shell, even though that particular individual has attained the maximum size for the species.

The interarea is usually short for the species but some individuals that lived in conditions so crowded that the hinge could not develop normally, became narrow hinged and long beaked; with consequent extremely long interareas. Specimens with short interareas normally are not provided with well-developed elytridia. These seem to be normal for the species but some specimens, usually old ones, show elaborate development of the elytridium. In such cases the elytridium is anteriorly flared or even alate. Spines given off from the elytridium are present in a number of specimens. As in other members of the Aulosteginae the elytridium assisted in the articulation of the valves.

**INTERIOR.**—The development and variation in the structures of both valves are of considerable interest. In the pedicle valve the muscle fields is of special significance.

**PEDICLE VALVE.**—The area occupied by the diductor scars is restricted posteriorly by deposition of adventitious material which forms a broad, smooth area, in marked contrast to the spreading dendritic patches of the posterior adductor scars. Consequently, the diductor scars are more rectangular than fan-shaped, as in some other productid genera.

The adductor field is normally long and narrow but in some specimens it flares anteriorly. The adductor field is divisible readily into anterior and posterior pairs of scars. The anterior pair is fairly simple and consists of an elongated inner scar and a shorter outer one. In the form of these scars, no two specimens seem to be alike. In some the outer scars are separated from the inner one, but in others they may be joined to the inner scar. What is uniform, however, is the clear distinction between the anterior and posterior scars.

The posterior pair of scars is elongate and varies in position from distinctly posterior, only overlapping slightly posterolaterally, to definitely lateral and extending but a short distance posteriorly. The posterior scars are finely dendritic and thus form a strong contrast to the simpler pattern of the anterior scars. In some specimens the anterior pair divides the field from front almost to back, but the posterior scars usually unite behind the anterior ones. Although the details of

both pairs of scars are extremely variable, the scars, nevertheless, have a sameness in their pattern. A similar situation exists with the adductor field of the brachial valve.

**BRACHIAL VALVE.**—The pattern of scars in the adductor field of this valve is almost exactly like that of the pedicle valve. The field is divisible into an anterior and a posterolateral pair of scars but the latter does not unite behind the former. The anterior pair of scars, like those of the pedicle valve, consist each of two tear-shaped scars, a long inner one and a shorter outer one, the two commonly joined posteriorly at their narrow ends. Many specimens, however, show a separation between them. The inner scar usually extends posteriorly for the entire length of the adductor field and separates the anterior from the posterolateral scars.

Lying obliquely outside the inner scars are the finely dendritic posterolateral adductors. The pattern of these scars is quite elongate and fairly strongly elevated in some specimens. The dendritic nature of the posterolateral scars is not clearly observable until the shell has attained a length of about 15 mm. The anterior pair retains its twofold character in the youngest specimens in which the scars are clearly visible (12 mm). Below this size, or in larger but less mature shells, the scars cannot be readily individualized and the anterior and posterior pairs appear to form a single elongate, tear-drop-shaped impression. In the oldest specimens the inner pair of scars, which is usually clearly separable from the posterolateral set in younger adults, tends to break into short patches separated by grooves. When this occurs the anterior pair loses its individuality.

**CARDINAL PROCESS.**—This structure exhibits most of the changes observed in *Echinosteges* but in many specimens the antron is completely obliterated. Of considerable interest is the strong development in most adults of the small projections or lobes that appear on the shaft. These have been interpreted (Muir-Wood and Cooper, 1960) as diductor muscle attachments but their small size in American genera make this idea uncertain. No clearly defined scars have been seen in *Edriosteges*.

In very old specimens the cardinal process reaches an enormous size and bears no resemblance to the youthful hollow form. Trilobed and quadrilobed forms are fairly common, and the myophore migrates through a large angle to face in a posterodorsad direction.

A feature of the brachial valve interior characteristic of *Edriosteges*, but not developed in *Echinosteges*, is the peripheral rim. Prematurely adult forms exhibit this feature but generally it is well developed only in mature or gerontic adults. It takes the form of a ridge originating on the ears, and in some specimens continuous with the lateral ridge, which extends anteriorly and surrounds the interior and locates on the edge of the anterior slope. In some specimens it is moderately strongly elevated especially just anterior to the ears. This ridge appears to be a response to deepening of the pedicle valve in growth.

**ECOLOGY.**—No details observed in the ecology and life habits of this species are significantly different from those of other similarly attached forms.

**REMARKS ON STRATIGRAPHY.**—This species is common at USNM 702c, where specimens are exceptionally well preserved. At this place the species does not attain as large a size as the largest specimens from USNM 703a. The species occurs at two distinct levels, one is at the top of the section, where a series of bioherms directly underlies the thin, carbonaceous limestone of the Road Canyon Formation. The other occurs far below this level where bioherms with abundant *Leptodus* also contain *Edriosteges* that differ somewhat from the younger specimens. Many of the specimens collected at this lower level are slightly less convex than the specimens from the Road Canyon. Mixed with these, however, are specimens having the normal characteristics of the species. Unfortunately, the collection is not large enough to determine whether or not a new species is present.

The same remarks will hold for specimens from the Cathedral Mountain Formation from USNM 702, 702a, 702un, 702inst., 702b, 711q, 714w, 703bs, localities that represent about the same level (that of the base of the Leonard as defined by King). Many of these specimens fall into the range of variation of the species but some have finer spines and generally are not so convex as normal for the species. Again the collection is too small to make specific differentiation.

### *Edriosteges tenuispinosus*, new species

PLATE 222: FIGURES 1–5

Large for genus, subquadrate in outline, width and length almost equal; cardinal extremities

obtuse; sides and anterior margin gently rounded; lateral profile moderately convex, posterior third somewhat flattened; anterior profile broadly domed and with steep sides; umbonal region flattened; median region inflated. Surface marked by short, slender ornament spines, closely crowded and covering surface; rhizoid spines thin and delicate. Interarea long; elytridium narrow, moderately elevated. No frill.

Brachial valve broadly concave, most concave in anterior third; ears flattened; lophidium elevated.

**MEASUREMENTS** (in mm).—From locality USNM 703a<sup>1</sup>, specimen 152650 (holotype): length 50.4, brachial valve length 40.0, maximum width 53.2, hinge width 41.2, height 19.7, thickness 13.6.

**STRATIGRAPHIC OCCURRENCE.**—Cathedral Mountain Formation.

**LOCALITY.**—USNM 703a<sup>1</sup>.

**DIAGNOSIS.**—Large, shallow *Edriosteges* with short, fine ornament spines.

**TYPES.**—Holotype: USNM 152650.

**COMPARISONS.**—This is the largest species of *Edriosteges* from the Glass Mountains and differs from *E. multispinosus* Muir-Wood and Cooper not only in size but in being shallower and less domed in anterior profile, in having finer ornament spines, no frill, and more delicate rhizoid spines.

### *Edriosteges* species 1

A few specimens taken from the sponge reef or bioherm in the Taylor Ranch Member of the Hess Formation at USNM 702d appear to belong to *Edriosteges* rather than *Limbella*. The ornament spines are well scattered and no costellae are apparent on any specimen. All the specimens are misshapen and show the effects of living in crowded conditions. The most complete specimen is 30 mm long by 28 mm wide, but the hinge is greatly narrowed by impeded growth caused by crowding. No median sulcus is evident in the pedicle valve. The interarea is fairly long. The brachial valve is gently concave and on the inside has aborted lateral ridges like those of more normal species of *Edriosteges*. The adductor field is not thickened but the cardinal process is stout-shafted and bilobed. The lophidium is keeled.

These specimens are of special interest because they are probably the earliest members of this genus from the Glass Mountains and possibly the oldest known anywhere.



**TYPES.**—Described specimens: USNM 149068, 149146.

**Genus *Echinosteges* Muir-Wood and Cooper, 1960**

*Echinosteges* Muir-Wood and Cooper, 1960:101.—Williams et al., 1965:H455.

Large, plano- to concavo-convex, subquadrate or rectangular to subpentagonal aulostegids having spiny pedicle valve but nonspiny brachial valve; rhizoid spines abundant on ears and posterolateral margins; ornament spines short, suberect; pedicle valve tuberculate to indistinctly costate anteriorly, tubercles bearing ornament spines; brachial valve dimpled and wrinkled, spines rare.

Pedicle valve with long palintrope, very narrow delthyrium and elevated elytridium; adductor scars restricted to elongated elevated platform; diductor scars flabellate, not extending anterior to adductor platform.

Brachial valve with prominent lophidium; cardinal process moderately long-shafted, deeply excavated anteriorly in young, solid and massive in adults; myophore varying from narrowly bilobed to widely bilobed to massively trilobed; posterior margin flattened; lateral ridges indistinct or poorly formed; adductor scars situated on thick rounded platform, anteriorly, laterally, and medially excavated; brevisseptum originating within adductor field, extending anteriorly to slightly beyond midvalve; brachial ridges indistinct except in old specimens, given off horizontally; brachial loops normal.

**TYPE-SPECIES.**—*Aulosteges tuberculatus* R. E. King (1931:95, pl. 27: figs. 4–7).

**DIAGNOSIS.**—Large Aulostegidae with long interarea, strong elytridium, short halteroid spines, and large brush of rhizoid spines on the ears.

**COMPARISON.**—This genus stands in strong contrast to *Limbella* and *Edriosteges* in spite of the fact that it has some of the characters of both. It differs from *Limbella* in its squarish outlines, the deeply and numerous dimpled brachial valve, and the numerous short halteroid spines. It differs from *Edriosteges* in the greater development of the palintrope and elytridium, lesser depth of the pedicle valve, and the lack of any radial ornament, which is also a distinction from *Limbella*. Internally, the brachial valve in the type species develops a strong adductor platform but not all of the species are so provided.

**DISCUSSION.**—This is a common genus in the Word Formation of the Glass Mountains but is extremely rare in the limestone below the Getaway Member of the Cherry Canyon Formation and in the Bell Canyon Formation of the Guadalupe Mountains. In the Word Formation of the Glass Mountains it is commonest in the Willis Ranch Member, fairly common in the China Tank Member, but less so in the Appel Ranch Member. The genus first appears in the Road Canyon Formation but is rare there. In rocks of post-Word affinities the genus is excessively rare. It is known outside the United States from Word equivalents in Coahuila, Mexico (USNM 149022). This lot includes an exceptionally large specimen and may represent an undescribed species, but the specimens are not well preserved.

*Echinosteges* relies for its fixation very largely on the rhizoid spines, which are more greatly developed than in most of the aulostegids of the Glass Mountains. These thick, stout spines are confined to the posterior margin, to the umbonal slopes, and to the lateral margins to midvalve or slightly beyond. When individuals live crowded together, the posterior ends become engulfed in a tangled mass of rhizoid spines. The ornament spines are short and suberect, projecting from their tubercle obliquely to the surface. These spines are thick at the base but taper rapidly.

Another feature of the exterior that needs remarking is the frill that develops around the anterior margin of both valves of old specimens. Although this frill or “gutter” was mentioned in the original description among the generic characters of *Echinosteges*, it is definitely not a generic character. Its occurrence is too spasmodic to assist in defining the genus. Furthermore, similar frills appear in other genera, either spasmodically or, in one genus, in most of the specimens seen. The frill is commonly thin and very fragile. In many specimens it appears only as remnants because of its fragility.

In the original description of this genus (Muir-Wood and Cooper, 1960:102), some points of anatomy were not considered in detail and a few statements need clarification. On the exterior of the shell, the brachial valve is said to have spines “very rare near hinge.” Although we examined many brachial valves, none proved to have spines near the hinge. One very unusual specimen (USNM

149019a, pl. 224: fig. 7) did, however, have large spines which, unexpectedly, prove to be rhizoid spines. These appear attached to the frill along the lateral margin of a large brachial valve. The spines are stout and thick; they grow nearly vertically from the frill for about 5 mm, after which they bend at a right angle to grow parallel to the shell surface for about an inch. They then descend with a moderate slope to attach to the surface along which they run to the opposite margin. The specimen unfortunately is fragmentary, but no attached spines appear on the valve surface that could be identified with a possible set of spines emanating from the frill on the opposite side of the specimen. Probably this is an aberrant individual. Obviously, this unusual occurrence does not affect the definition of *Echinosteges* as having a brachial valve free of spines.

Of considerable interest on the pedicle valve are the palintrope, interarea, and the elytridium, which are best developed in this species of all the Glass Mountains aulostegids. As with all attached forms, the length and width of the palintrope and interarea are extremely variable. Some specimens that have been forced to grow squeezed tightly between their fellows usually have an enormously elongated palintrope. In such specimens the elytridium is exceptionally well developed. The delthyrium or cleft in the palintrope is always extremely narrow, consequently the elytridium is narrowly folded and increases in height above the interarea anteriorly. At its anterior end the elytridium is puckered and grooved to accommodate the carinate edge of the lophidium. In many specimens the anterior end of the elytridium hangs over the lophidium and, in several specimens, extensions of its end are folded around the sides of the lophidium, tending to lock this structure in place. In such examples the elytridium serves fairly effectively as an articulatory device.

One of the generic characters stated for *Aulosteges* is the presence of small spines on the "delthyrium." This feature, which has been observed in a few specimens of *Echinosteges*, usually adults or old individuals, is occasionally deceptive, because spines grow from the posterior margin over the interarea and wrap over or cease growth at the elytridium. These examples appear to show the spines as emanating from the elytridium when actually they do not. But in a fair number of speci-

mens spines are given off directly and vertically from the narrowly rounded edge of the elytridium. These spines are hollow and open inside the valve through the elytridium. Spines from the elytridium are rare, but are used for attachment.

The palintrope edge in some specimens is minutely serrate, but no specimens were seen in which this becomes an important factor in the articulation. The interarea is marked by prominent horizontal lines of growth which interrupt vertical lines. These appear to be the growth tracks of irregularities along the margin.

Muscles occupy the entire posterior half of the pedicle valve. The diductors are large and flabellate but never strongly impressed. The adductor field, however, is prominent because of its elevation on a long and narrow platform dividing the diductors from back to front. The diductors do not extend anterior to the front end of the adductor platform. A thin, low, delicate myophragm divides the adductor platform into halves. The myophragm in many specimens is concealed by shell tissue and cannot always be observed, except in the anterior end of the platform. Four scars are visible in favorably preserved specimens. The two larger ones appear at the anterior end, and the smaller, narrower ones at the posterior. Both pairs commonly become dendritic with age. In some specimens the scars can be seen on the sloping side of the platform as well as on the top.

The development of the adductor platform is extremely variable, even in young shells. In some young adults it is only slightly elevated above the floor, but in some youthful ones it is strongly elevated. The age of the shelf or platform may be deduced from the character of the scars on it. In the young, the surface of the scars is smooth and the margins fairly well-defined; but in old platforms the scars are generally dendritic, and the outline of individual muscles difficult to trace.

The structure of greatest interest in *Echinosteges* is the cardinal process, which undergoes considerable change from the young to the adult. In immature specimens the cardinal process is elongated, extending into the body chamber at right angles to the posterior margin, and forming a tentlike structure. In cross section it is triangular and is deeply excavated on the anterior side but carinate on the posterior side. The myophore is narrowly compressed, consisting of three unequal lobes, the me-

dian lobe being the larger; the two lateral ones are depressed anteriorly, forming ridges below the level of the median lobe, and are separated from the median one by narrow grooves and the sloping lateral faces of the median lobe. The myophore occupies about the ventrad half of the posterior carinate face, the other half being the sharp edge of the lophidium. In some specimens the distal tip of the cardinal process is slightly indented medianly. When emphasized, this indentation may lead to a quadrilobate process but this is not a common condition.

Considerable variation exists between individuals below 5 mm length in the development of the cardinal process. In many specimens the process is small and short but in others it is robust and thick, with stout lateral pillars forming the sides. The myophore ranges from narrowly compressed to moderately expanded, with the appearance of that of a larger adult. It is possible to explain these differences as the result of living in unfavorable or in favorable environments.

The more precocious processes may have developed in specimens situated where food and oxygen were in proper supply; the specimens with weaker development of the process may have been undernourished. On the other hand, those with the stouter and more advanced cardinal processes may represent individuals that are essentially adult but dwelt in an inhospitable environment for such a long period that they attained adulthood without reaching normal adult size.

Specimens ranging in size from 5 to 25 mm show the same variations in development from immature cardinal processes to those types more typical of old age, even though a specimen an inch long is still young. In spite of the range, certain advances can be noted in the majority of specimens. Generally, the distal end of the process is wider than in the very young, and the median lobe of the myophore is more prominent. In all specimens observed, the anterior face is deeply excavated but the lateral walls are thicker, and in many specimens a small projection appears near the proximal base of the cardinal process wall, or nearer the middle in some specimens. These projections show incipiently in many small specimens and are seldom strongly developed at a length of one inch (25 mm).

No consistency was observed in the expansion of the distal end of the myophore. Some extreme examples have a widely bilobed end, but the majority

of specimens are only slightly expanded at a length of one inch. Many of them have scarcely advanced from the narrowly compressed stage of the very young.

Brachial valves ranging in length from one inch (25 mm) to nearly 2 inches (45 mm) exhibit still greater variation in the cardinal process than the smaller valves. In general, a great thickening of the process takes place, and in a fair percentage of specimens the anterior excavation is totally eliminated, the shaft becoming filled and overgrown by callus. Exactly as in the smaller specimens, individuals of large size appear whose cardinal process shows little change from its youthful form. For example, one specimen 35 mm long has a cardinal process open anteriorly, except near the ventrad end, where it is thickened and slightly grown together and the myophore is tightly compressed. Anterior points that are common in many specimens are still in an incipient condition. This specimen contrasts with another, 41 mm long, in which the anterior cavity is completely closed, and the two processes are prominent and partially cover the anterior face. The myophore of this specimen is deeply cleft medially and the cardinal process distally is strongly bilobed, the lobes widely divergent. This specimen may be compared to another of the same length but of heavy shell and massive cardinal process. A cavity appears at the base of the process and is bounded by massive lateral plates. The remainder of the anterior face is covered by enormously expanded lateral lobes of the cardinal process and a large development of the two pointed processes. The myophore of this specimen is characterized by a forked median lobe of moderate size with two massive lateral lobes on each side, making the cardinal process 15 mm in lateral measurement. The lophidium is correspondingly thickened and the specimen shows all signs of having had a healthy old age.

The largest brachial valve in the collection is 47 mm long. It is not as thick as the preceding specimen but has all of the marks of extreme old age. The cardinal process is about the same width as that of the preceding specimen, and the median lobe is not cleft but forms a rounded lump. The extravagant feature is the lateral lobes, which are greatly expanded and have broader attachment surfaces than normal. The lophidium in this case is narrow and sharp.

The elevated adductor platforms are an impor-

tant feature of *Edriosteges*. In the youngest specimens available (about 5 mm long) the platforms are conspicuous but not greatly elevated. As with other features, however, this statement must be qualified. In some specimens the platforms are definitely lifted above the floor and are anchored by a low plate, the platforms being excavated fairly deeply medially. In older specimens the elevation becomes higher and the supporting plate more conspicuous. In addition the platform is excavated laterally as well as medially. In adults and old specimens the platforms are so thickened in some specimens that they coalesce, but in others they remain deeply excavated medially.

Generally in the young two scars are visible on each platform. These are somewhat teardrop-shaped and the smaller one lies on the outside of the larger. In old specimens scars become strongly dendritic, so much so, that it is usually difficult to distinguish the separate scars.

ECOLOGY.—*Echinosteges* lived like most of the other members of the Aulostegacea but differs from many genera in having the rhizoid spines confined to the posterior margin, umbonal slopes, and the posterior half of the lateral margin. Many aulostegids have anchor spines scattered on the body of the shell or along the front and anterior half of the lateral margins. Rhizoid spines have not been observed in these parts of *Echinosteges*. It is, perhaps, because of lack of anterior and lateral supports that the rhizoid spines are so thickly matted and massed at the posterior. The specimens that have been found in living position are firmly rooted by a dense mat of spines.

*Echinosteges guadalupensis* (Shumard)

PLATE 229: FIGURES 1–19; PLATE 244: FIGURES 28, 29; PLATE 258: FIGURE 30; PLATE 267: FIGURES 1–4

*Strophalosia guadalupensis* Shumard, 1860:292, 390, pl. 11: figs. 5a, b.

*Aulosteges guadalupensis* Girty, 1909:277, pl. 20: figs. 22, 22a. [Not of R. E. King, 1931:93, pl. 25: figs. 8–11, = *Rhamnaria kingorum* Muir-Wood and Cooper.]

Small and delicate for genus, longer than wide, outline longitudinally subtrigonal to rectangular; greatest width near midvalve. Sides moderately rounded; hinge narrower than greatest width; anterior somewhat narrowly rounded; anterior commissure with gentle dorsad flexure. Interarea long,

flat, apsacline. Elytridium large, long, strongly arched. Surface finely tuberculate on pedicle valve, tubercles bearing on ears and posterolateral slopes short (3.5 mm), nearly recumbent, ornament and brush of long but delicate rhizoid spines. Brachial valve finely and deeply pitted.

Pedicle valve fairly evenly and gently convex in lateral profile; anterior profile broadly but moderately domed with sulcate median region and steep, gently rounded sides. Umbonal region narrowly inflated with long and steep posterolateral slopes to small deflected ears. Sulcus fairly strong, originating at about midvalve and indenting anterior margin. Flanks swollen, lateral slopes steep; anterior slope moderately steep.

Pedicle valve gently convex in posterior third but becoming moderately concave anteriorly, with anterior quarter abruptly deflected ventrally to form steep slope lessening laterally and posteriorly and bounding deepest concave part on each flank of low median fold. Ears slightly developed, bounding deepest concave part on each flank of low median fold. Median fold originating just posterior to midvalve, angular and broad.

Pedicle valve interior with elongate adductor field, dendritic posteriorly and divided by low apical myophragm extending anteriorly not quite to middle of adductor field. Diductor scars subflabellate.

Brachial valve interior with broad ginglymus or false interarea. Cardinal process primitive, with long open shaft and bilobed myophore. Lophidium keeled but not strongly developed. Adductor field not strongly developed, with no trace of platforms; brevisseptum low and inconspicuous, often not visible.

MEASUREMENTS (in mm).—Hypotype, USNM 152652a: length 33.0, brachial valve length (?), maximum width 29.0, hinge width 22.2, height 11.7, thickness (?), interarea length 7.3. Hypotype, USNM 152652n, brachial valve: length (?), brachial valve length 27.9, maximum width 35.0, hinge width 21.7, height and thickness (?).

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler, Pinery, Rader and Lamar members), Capitan Formation.

LOCALITIES.—Hegler: USNM 731, 732a, 740c. Pinery: AMNH 397; USNM 725n, 736. Rader: AMNH 403, 410; USNM 725f, 725g, 740i, 740j. Lamar: 728p. Capitan: 738a.

TYPES.—Figured hypotypes: USNM 149407;



152652a, c, j, l, m; 154181; 154182a. Measured hypotypes: USNM 152652a, n.

COMPARISON.—This species is smaller, with delicate and more numerous spines than *E. tuberculatus* (R. E. King) the only other species known. The exterior of the brachial valve is more numerously and more finely pitted than that of King's species and it also has a median fold, a character not shared by the Word species.

DISCUSSION.—This is an extremely rare species in the Bell Canyon Formation. Beside the type lot from the Rader Member a few posterior portions of brachial valves were taken from several localities. The Pinery Member (USNM 725n) produced three similar specimens but it is uncertain that they are specifically the same. Some of the specimens from the Rader, at other localities than that of the types, indicate that they were larger and thicker than the type specimens, but all of them have the same open-shafted cardinal process and immature type of myophore which is a mark of the species.

Specimens of *Echinosteges*, fully adult in size, often retain a juvenile kind of cardinal process. This is not characteristic of most species because many specimens, including ones with juvenile exterior proportions, develop elaborately lobed cardinal processes. Possibly if enough specimens of *E. guadalupensis* are found they may show that this species, too, developed a more advanced cardinal process in old age in a small percentage of the specimens.

On the basis of the shape of the specimen figured by Shumard (1860: 390, pl. 11: figs. 5a, b), with its elongated beak, the specimens described above have been identified as Shumard's species. Similar specimens but with low beaks have the characters of *Rhamnaria* and cannot be identified as Shumard's species. Specimens were taken in the limestone as well as from the residues but it is a rare species.

### *Echinosteges tuberculatus* (R. E. King)

PLATE 101: FIGURE 14; PLATE 223: FIGURES 23, 24; PLATE 224: FIGURES 1–10; PLATE 225: FIGURES 1–19; PLATE 226: FIGURES 1–18; PLATE 227: FIGURES 1–25; PLATE 228: FIGURES 1–43; PLATE 229: FIGURES 20–38

*Aulosteges tuberculatus* R. E. King, 1931:95, pl. 27: figs. 4–7.  
*Aulosteges beedei* R. E. King, 1931:92, pl. 25: fig. 15 [not figs. 12–14 = pl. 101: fig. 14].

Large, quadrate to subrectangular but commonly

misshapen; length and width nearly equal; hinge variable, narrow to nearly equal to greatest width; sides straight to gently curved; anterior margin broadly rounded; anterior commissure faintly uniplicate; surface tuberculate and spinose.

Pedicle valve with prominent tubercles covering exterior, each tubercle bearing recumbent stout ornament spine about 6 mm long or less; ears bearing tangled masses of long rhizoid spines by which shell is anchored. Tubercles on anterior slope in many specimens elongated into prominent costae. Anterior margin of old specimens provided with ventrally reflected flange, or gutter. Lateral profile unequally convex, posterior half nearly flat to gently convex, but anterior half strongly convex and with precipitate anterior slope. Anterior profile strongly domed, sides steep and long. Beak small, slightly incurved over interarea; umbo rounded to greatly elongated, moderately convex; median region swollen. Palintrope long, divided by narrow delthyrium; interarea flattened or curved and irregular; delthyrium closed by narrow and irregular elytridium. Palintrope margin straight and unmodified.

Pedicle valve interior with open and spacious umbonal chamber with elongated and strongly elevated adductor field in the middle. Four scars, inner and outer pairs, discernible; adductor scars commonly dendritic. Diductor scars seldom well impressed, broadly flabellate, not extending beyond tip of adductor platform. Anterior half pitted, marked by taleolae.

Brachial valve generally square in outline, variable in profile, ranging from almost flat to slightly convex and to unevenly concave, latter examples being gently convex in posterior half but gently to moderately concave in anterior half. Exterior concentrically but unevenly wrinkled and pitted by irregular dimples corresponding to tubercles of pedicle valve; no spines observed. Interior with posterior margin thickened from cardinal process to flattened and narrowly rounded ears. Cardinal process variable, deeply excavated anteriorly; shaft short, consisting of two pillars bridged by keeled myophore in young but bilobed to trilobed myophore in adults. Adductor platforms prominent, elevated on low ridges and overhanging or pinching out median septum; platforms excavated laterally and medially; brevisseptum extending from anterior end of adductor platforms to

beyond midvalve; brachial ridges obscure, originating at anterolateral ends of adductors and extending directly laterally. Anterior margin in many

specimens with ventrally deflected flange, or gutter, corresponding to that of pedicle valve and outside of it.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	maximum width	height	thickness
USNM 706c							
149020a	53.2	?	75.0	35.0	47.8	20.0	?
149020b	49.1	?	71.0	35.5	42.0	19.0	?
149020c	39.8	?	49.0	29.0	33.5	16.9	?
149020d	33.8	?	40.0	32.0	32.0	10.6	?
149020e	30.0	?	33.5	21.5	29.5	7.8	?
149020f	27.7	?	33.0	21.5	25.0	8.1	?
149020g	24.8	?	28.5	18.0	22.0	7.2	?
149020h	20.2	?	20.5	21.5	22.3	7.8	?
149020i	16.6	?	18.5	13.0	16.0	3.5?	?
149020j	9.0	?	10.0	10.0	10.5	3.0	?
149020k	6.5	?	7.0	7.5	7.5	1.7	?
149020l	3.7	?	3.5	3.5	5.0	1.1	?
149020m	?	38.2	?	41.0	44.0	?	?
149020n	?	33.0	?	35.3	39.0	?	?
149020o	?	31.6	?	26.5	35.6	?	?
149020p	?	27.1	?	19.0	22.7	?	?
149020q	?	18.7	?	17.3	21.0	?	?
149020r	?	12.8	?	13.7	14.1	?	?
149020s	?	8.0	?	6.4	8.0	?	?
149020t	41.1	32.4	52.0	30.5	37.9	15.8	10.1
149020u	25.8	21.0	30.0	23.0	28.6	8.5	8.3
USNM 706b							
149024a	48.8	35.2	56.0	37.4	45.2	17.1	13.1
149024b	58.0	41.6	88.0	45.5	59.8	36.0	28.0

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member), Road Canyon Formation, Word Formation (China Tank, Willis Ranch, and Appel Ranch members and lenses between last two).

LOCALITIES.—Road Canyon: USNM 716xa, 720d, 721j, 732j. Cherry Canyon: AMNH 21, 496, 512, 600; Moore 31; USNM 728, 730, 732. Word: USNM 732c, 732s, 741p. China Tank: USNM 706c, 713, 733q. Willis Ranch: AMNH 505, 506; USNM 706, 706e, 723t, 723w, 724u, 735c=706e. Appel Ranch: USNM 714o, 716v, 726t. Lenses: USNM 706b, 742b.

TYPES.—Lectotype (herein designated): YPM 10608a. Figured paratype: YPM 10608b. Figured specimen: T11045. Figured hypotypes: USNM 123452; 123453a, c, k-m, p; 123905a, b, e, f, h, i, k; 149019a-j, l, m; 149020u; 149024a, b; 149026; 149039a, b; 154177a; 154178a-e, h, j-l; 154179a-d, f, g, j-l; 154180a-c, f, g, k-q; 154529. Measured hypotypes: USNM 149020a-u; 149024a, b.

COMPARISON.—This species differs from *E. guad-*

*alupensis* (Shumard) in its larger size, more robust form, stronger spines, and more advanced internal characters in the brachial valve.

TYPE-SPECIMENS.—R. E. King (1931:95) failed to designate a holotype for his species. We therefore select the specimen illustrated on plate 27: figure 7 as lectotype. This specimen is a large and fully mature adult from the Word Formation (Willis Ranch Member).

Selection of this specimen is mandatory because King (p. 95) indicates his "types" from his locality 239. The only other specimen from this lot is fragmentary. These specimens are from the same stratigraphic level as the abundant ones from USNM 706e and those figured by Muir-Wood and Cooper (1960, pls. 14-16).

*Echinosteges?* species

PLATE 258: FIGURES 31, 32

A probable new species is represented by a frag-

ment from the Neal Ranch Formation at USNM 701. The specimen is the posterior part of a pedicle valve having a broad and flat, strongly apsacline interarea with a narrow and slightly elevated elytridium. The exterior is covered by a mat of very fine spines. This is the only trace of this genus or other aulostegid except *Limbella* found in the Neal Ranch Formation. The delicacy of the spines sheds some doubt on the generic assignment.

TYPE.—Figured specimen: USNM 149045.

### *Cactosteges*, new genus

[Greek *cactos* (prickly plant) + *steges* (chamber)]

Moderate size, subquadrate in outline, plano- to concavo-convex with the pedicle valve of considerable depth; anterior commissure faintly uniplicate; surface of both valves spinose, pedicle valve attached to substrate by rhizoid spines located on the ears, umbonal slopes, and lateral margins and bearing short, slender prostrate ornament spines; brachial valve with delicate erect spines; pedicle valve marked by concentric undulations and nodose spine bases arranged in concentric rows; brachial valve marked by concentric undulations, shallow pits.

Pedical valve with incomplete palintrope on each side of beak separated by triangular delthyrium; palintrope marked by flat interarea; region just anterior to palintrope thickened and forming platform; pitted along palintrope margin. Inner lateral slopes marked by large internal, hollow spines; adductor scars thickened and elevated to form low platform; diductor scars truncate anteriorly, wide, surrounding adductors and occupying most of posterior half of valve.

Brachial valve with large bilobed to trilobed cardinal process with expanded myophore and thick shaft; lophidium prominent, plugging delthyrium. Posterior margin thickened and marked by irregular row of nodes; median septum thin, low but extending from cardinal process shaft to beyond midvalve; brachial ridges large but indistinct; endospines large and in row along anterior slope.

TYPE-SPECIES.—*Cactosteges anomalus*, new species.

DIAGNOSIS.—Aulostegidae having spines on both valves, incomplete palintrope in pedicle valve, and brachial valve with prominent endospines on the summit of the anterior slope.

COMPARISON.—At first glance *Cactosteges* is most

like *Echinosteges* Muir-Wood and Cooper, but interior and exterior differences readily separate the two. On the exterior *Echinosteges* is strongly tuberculate but it has few, if any, spines on the brachial valve. The interior differences are more numerous. *Echinosteges* is characterized by a broad and conspicuous palintrope in which the delthyrium remnant is covered by an elytridium. A corresponding cover has not been seen in any specimen of *Cactosteges*. Furthermore, the palintrope hangs free over the umbonal chamber and is commonly very long in *Echinosteges*, but in *Cactosteges* the palintrope either overlies the marginal edges or is greatly thickened underneath, so that it does not hang free at all or only for a short distance. The thickenings around the palintrope of *Cactosteges* and their possible value in articulation is a feature not seen in *Echinosteges*.

Inside the brachial valve important differences between the two genera are still clearer. In *Echinosteges*, the cardinal process of young specimens is strongly excavated anteriorly, the shaft is short, and the lophidium greatly exaggerated. In *Cactosteges* the lophidium is small in all stages, the shaft is longer, and the process is not anteriorly excavated. A difference between the septa and associated adductor platforms is also perceptible. In *Cactosteges* the median septum extends from the cardinal process shaft to beyond midvalve and is continuous all the way. Furthermore, the adductor scars are only moderately elevated and in the young are never anteriorly excavated. In many specimens of *Echinosteges* the median septum is visible only from the anterior of the adductor platform to beyond midvalve and the adductor platforms are greatly elevated and usually are deeply excavated anteriorly. In *Echinosteges* the brachial ridges are indistinct, as they are in *Cactosteges*, only appearing in old adults and never with a development of long endospines on the summit of the anterior slope, as in *Cactosteges*.

DISCUSSION.—*Cactosteges* presents some interesting points in brachiopod anatomy not commonly seen among productid brachiopods. One of these concerns the development of adventitious shell in the region immediately anterior to the palintrope, and its bearing on articulation of the valves. Among the productids it seems clear that the cardinal process and delthyrium are accessories to articulation but in some genera adventitious deposits in the form of nodes and sockets appear to have helped

toward the same goal. In young specimens the palintrope is only slightly developed, but in adults it is fairly well marked, overhanging the deeper part of the umbonal chamber. In a few specimens the palintrope is thin enough to have been fractured where it is free and, in this condition, simulates the perideltidial area of Dunbar (in Dunbar and Condra, 1932).

In most adults the palintrope is supported and thickened underneath, and a shelf of adventitious shell is built anteriorly against the under side of the palintrope, against the lateral wall of the umbonal chamber, and nearly flush with the flattened ears. This creates a shelf, underlying the palintrope on which the brachial valve rests, that is commonly marked by a row of pits along the junction of the adventitious shell and the under side of the palintrope. In some parts of the row the pits are shallow but in others they are fairly deep. These pits receive nodose projections from the posterior of the brachial valve.

The posterior margin of the brachial valve of this species is marked on each side of the lateral slope of the cardinal process shaft by an irregular row of round nodes suggesting, in some specimens, small bunches of grapes. These nodes articulate with the sockets in the pedicle valve alluded to above and seem to be modified taleolae, although it is difficult to prove the point in silicified material.

The palintrope of the pedicle valve is generally divided by a delthyrium that is fairly wide in this genus. This opening is usually plugged by the large triangular lophidium of the brachial valve, but in some specimens this plate does not suffice to close the opening. In such shells an incipient elytridium is formed, but it is seldom well developed and its presence is rare. In many specimens the narrow space between the end of the delthyrium and the beak is filled by shell material to make a solid wall against the end of the lophidium of the brachial valve.

The pedicle valve musculature is not always well defined in this genus. The adductor field is usually thickened, in some cases greatly so, but the diductor scars are seldom clearly seen. The adductor scars are usually elongate, teardrop-shaped platforms, divisible, in some rare specimens, into anterior and posterior pairs. In some old specimens an additional lateral teardrop-shaped pair appears, one on each side of the main two. The diductor scars, when visible, are large and flabellate, as usual in the

productids, and surround the adductor pair. Several other features of interest that appear in most pedicle valves of this genus should be mentioned. Anterior to the muscle field the median region of the interior is gently folded or thickened. This area is marked by short, oblique endospines with their pointed ends directed anteriorly. This endospinose area corresponds with that of the brachial valve.

On the inside of the steep, lateral walls just anterior to the ears and extending nearly to the anterolateral extremities appear oblique elevated lines. They are undoubtedly parallel to the direction of the currents entering the valve when the animal fed. A corresponding area appearing in the brachial valve is mentioned below.

Another feature that appears in the same place is the one or more rows of short, hollow spines on the interior. In general, these are essentially parallel to the markings mentioned above and are open at their free end; apparently they connect with large spines on the exterior of the shell.

As in most productids the cardinal process of *Cactosteges* is variable, so much so in some specimens that identification is difficult. In the youngest specimen recognized as belonging to this genus, the cardinal process extends ventrally at right angles to the posterior margin; it is without a shaft and is thickened and solid on the anterior side. The myophore is bilobed and the lobes are separated by a moderately deep reentrant. The lophidium is prominent. Adults exhibit a variety of forms, most of which retain the prominent bilobed outline when viewed from the ventral side but have developed a moderately long shaft that is oblique to the posterior margin. In the posterior side the myophore is somewhat expanded and is trilobed, a large median lobe being separated by two diverging slits from the lateral lobes. In a few specimens the median lobe is so strongly developed that the cardinal process is trilobed in ventral view.

Another feature of the cardinal process is the development of two pointed processes, or points, that extend anteriorly and obscure the shaft. The median ridge in the young extends to the cardinal process; in older forms it may be visible or may be obscured by medial growth of the adductor platforms or may be buried in shell deposit.

The ears of the brachial valve are fairly prominent and flattened. They are set off from the main part of the shell by an oblique baffle that extends from the posterior margin to the lateral



margin at or near midvalve. This baffle evidently makes contact with the inner wall of the pedicle valve, where it is obliquely striated. The baffle of the brachial valve is striated like that part of the pedicle valve against which it abuts. Incurrent feeding streams may have passed through the narrow passage made between baffle and pedicle shell wall when the valves gaped.

*Cactosteges anomalus*, new species

PLATE 230: FIGURES 1-49; PLATE 231: FIGURES 44-56

Outline irregular, generally somewhat quadrate, with lateral margins slightly oblique, anterolateral margins narrowly rounded and anterior margin broadly rounded. Lateral margins just anterior to ears slightly indented. Hinge narrower than greatest width, which is near or anterior to middle. Rhizoid spines long, moderately stout, concentrated on ears and umbonal slopes but scattered along lateral margins. Halteroid spines thin and sharp, about 3 mm long. Interrupted concentric undulations marking pedicle valve and irregular concentric undulations and pits appearing on brachial valve. Brachial valve spines short and delicate.

Pedicle valve unevenly convex in lateral profile, maximum convexity anterior to midvalve and posterior half or more nearly flat; anterior profile highly domed but with top flattened and sides steep. Umbo narrowly swollen near beak, gently convex and with gentle slopes laterally; median region greatly swollen, with precipitate anterior and anterolateral slopes; sulcus narrow and shallow,

irregularly developed, but usually originating at or posterior to midvalve and extending to anterior margin; ears small, not prominent, forming rounded obtuse angles.

Pedicle valve interior with short palintrope, flat or somewhat curved, and divided by an open delthyrium; region anteroventral to palintrope greatly thickened and roughened; ears small and usually somewhat concave; inner umbonal slopes marked by hollow tubes in rows just under margin; adductor platforms low; diductor scars large but not deeply impressed.

Brachial valve fairly evenly concave, concavity varying from gentle to moderately deep; umbonal region concave; lophidium forming small triangle on posterior margin; ears small, varying from indistinct to narrowly acute.

Brachial valve interior with variable cardinal process moderately long-shafted, with bilobed to trilobed myophore, the younger specimens having prominently bilobed myophore with deep median slit on ventral face but old specimens with thick trilobed myophore, the two median lobes having coalesced to produce a single thick lobe; median septum variable, ranging from high to low but usually uniting with cardinal process shaft and extending anterior to midvalve; adductor scars elongate and somewhat teardrop-shaped, inner two usually thickened to form prominent platform that may partially obscure or squeeze against median septum. Brachial ridges obscure, oblique at point of origin and marked anteriorly by row of long endospines situated along line where anterior slope of concave valve originates.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	maximum width	height	thickness
USNM 706							
151297a	15.0	12.5	21.0	11.2	14.8	5.9	4.8
(holotype)							
151297b	13.3	12.5	17.0	12.3	14.5	4.6	2.9
151297c	11.2	10.9	14.0?	8.7	12.5	4.1	2.3
151297d	13.3	10.8	23.0	11.8	14.7	8.2	6.0
151297e	16.4	?	29.0	13.0	19.7	10.7	?
151297f	15.7	?	18.0	12.5?	18.5	5.4	?
151297g	13.8	?	18.0	13.9	17.3	4.8	?
USNM 706c							
151299a	13.8	11.3	17.0	10.5	14.7	5.3	3.5
151299b	14.7	12.2	21.0	10.5	15.9	6.8	4.7

**STRATIGRAPHIC OCCURRENCE.**—Road Canyon Formation, Word Formation (China Tank and Willis Ranch members).

**LOCALITIES.**—Road Canyon: USNM 716xa, 720d, 721j. Word: USNM 732s. China Tank: USNM 706c, 713, 721p, 726r, 733q. Willis Ranch: AMNH 506; USNM 706, 706e, 718d, 723w, 724u, 735c.

**DIAGNOSIS.**—Convex, small Echinosteginae with distant strong, ornament spines.

**TYPES.**—Holotype: USNM 151297a. Figured paratypes: USNM 151296a, b; 151297d-f, 151298; 154150a-c; 154151a-d; 154152a-j. Measured paratypes: USNM 151297b-g, 151299a, b. Unfigured paratypes: USNM 151297a-c, 154150d.

**COMPARISON.**—No other species of this genus is known with which this one may be compared. It may be confused with small individuals of *Rhamnaria* but can be distinguished by *Rhamnaria*'s densely nodose shell surface, each node bearing a slender spine. The effect is of a much more strongly and finely spinose shell than is usual in *Cactosteges*. Internally, the pedicle valve of young *Rhamnaria* has a vestigial median septum, another ready distinction between the two.

**DISCUSSION.**—As presently constituted this species is one of the most variable of all productids. The extreme variability probably comes about because of the attached habit. This species is of about medium size for productids and when growing in crowded places may be greatly distorted. Specimens range from gently and fairly evenly convex to narrowly rounded or domed in lateral profile. The young are almost flat and even the most rotund specimens must have had this nearly flat early stage. If the young grew in such a position that the anterior always remained free, the specimen would reach maturity with a gentle lateral profile. If, on the other hand, growth started in the apertural region of a richthofeniid, the anterior margin may become deflected in its growth at an early stage and produce an individual with narrowly rounded lateral profile. Indications are that this may have happened in the majority of cases, because no consistent difference has been discovered on which to separate species in the material at hand.

*Cactosteges anomalus* is an uncommon species at all of its localities. Most of the specimens come from the lower part of the Word Formation (Willis Ranch Member) at USNM 706, but it is nevertheless rare at this place. Specimens from USNM 706e

seem slightly larger than from the previous place and some features such as the endospines of the pedicle valve, are better preserved on them than on others from elsewhere.

### Genus *Xenosteges* Muir-Wood and Cooper, 1960

*Xenosteges* Muir-Wood and Cooper, 1960:111.—Williams et al., 1965:H455.

Small, concavo-convex, attached; hinge variable, usually wider than midwidth; anterior commissure slightly uniplicate; outline subquadrate, varying from nearly square to transversely rectangular; surface smooth or marked by interrupted or discontinuous concentric wrinkles. Spines consisting of rhizoid spines only extending from posterior margin, ears, and umbonal slope. No ornament spines.

Pedicle valve with short interarea and open delthyrium; umbonal cavity deep; adductor field in old specimens forming triangular elevated track; delthyrium in old specimens partly closed by concave plate. Outer spines continued into interior in many specimens.

Brachial valve interior with variable cardinal process, usually short-shafted and with bilobed or trilobed myophore; adductor scars thickened to form prominent platform in adults; brevisseptum short but well elevated; no lateral ridges, but brachial ridges sloping at steep angle and commonly strongly elevated as projecting lobes; anterior slope minutely endospinose.

**TYPE-SPECIES.**—*Xenosteges adherens* Muir-Wood and Cooper (1960:112).

**DIAGNOSIS.**—Nearly smooth Aulostegidae, generally of small size, having rhizoid spines only and prominent, commonly elevated brachial ridges.

**DISCUSSION.**—The species of this little genus are easy to recognize because of their nearly smooth exterior and the presence of rhizoid spines only, restricted to the posterior portion of the pedicle valve. The growth habit of all members of this genus is like that of most other members of the family. The umbonal cicatrix of attachment varies in size from a mere spot to covering almost all the umbonal region. Unlike most members of the family that beak and umbonal region may be thinned by close attachment.

Although most specimens appear to be fairly solidly cemented by the umbonal region, many are

additionally securely anchored by rhizoid spines. The umbo of many specimens is a veritable forest of short anchor spines put out in the early stages of life. Later rhizoid spines are sent out from the ears and the umbonal slopes. Because of the small size of the specimens, most of these spines are short, but the spines in some did not stop growing after contact with the substratum. In some instances spines over 25 mm long have been measured, a length exceptional for such small shells.

*Xenosteges* imposed itself on many host objects. It favored the interior surface of *Neospirifer*, *Hercosia*, the larger productids, and any other niche that offered protection and stability.

The exterior features require little comment except for the ears. These are prominent in *X. adherens* Muir-Wood and Cooper but less so in other described species. Prominent ears appear to have been a feature of late adulthood. The ears of large or adult shells are usually well demarcated from the main body by a prominent change in slope and also by the strong convexity of the ear. These features are not so prominent in the Guadalupean species, which are more nearly square or elongate. Most of the younger specimens having incipient ears that appear as posterolateral bulges. *Xenosteges umbonatus*, new species, generally an elongate species with subdued ears, develops strongly swollen and prominent projections in old specimens that have had favorable living conditions. The young specimens of most of the species show the ears more prominently on the dorsal side, where they are usually set off by a change in slope or an oblique ridge.

The interior details of this genus offer some interesting features, including a general increase in the degree to which these are developed in the younger strata. In the pedicle valve the interarea is not strongly developed in any of the species. It is perhaps longest and widest in *X. adherens*, which attains a large size for the genus. In some specimens, especially large ones in which the posterior is thin, the interarea may be greatly reduced, even to disappearance. In specimens in which the interarea is well developed, as in some individuals of *X. quadratus*, new species, the delthyrium, which is always open to the exterior, is usually sealed on the inside by a concave plate. A few specimens of *X. adherens* show this plate, but not as fully developed as in *X. quadratus*. This small plate evidently forms

a groove in which the lophidium of the cardinal process moved.

Another sporadically developed feature of the interior is the presence of hollow spines on the inside of the pedicle valve. These are an extension of exterior spines into the interior, a phenomenon well developed in *Cactosteges*. The lateral and anterior border of *Xenosteges* is rounded and thickened to fit snugly into a groove around the anterior border of the opposite valve.

Young pedicle valves of *X. adherens* are very little thickened in the umbonal cavity and it is difficult to determine the size and character of the muscle scars. In old specimens the position of the adductor field is shown by a ridge or myophragm extending anteriorly from the beak. In many old specimens the areas on each side of the ridge are thickened to form an elongate, narrowly triangular elevation. The diductor muscles, which must have lain anterolateral of this platform, were not visible in any of the specimens examined.

In *X. quadratus* the triangular adductor field is more prominent, larger, and thicker, but the diductor scars are no clearer in this species than in the former. The elevated adductor track is a more prominent feature in this species than in the former and is strong in young adults as well as in older specimens. The adductor platform reaches its greatest development in *X. umbonatus*, new species, from the Guadalupe Mountains. In this species the platform is still wider than in the others and occupies the entire umbonal cavity. In some specimens it is so deeply excavated anteriorly as to form a separate plate above the valve floor. It is also divided medially by a moderately elevated myophragm. No clear impressions of the diductor scars are visible in our specimens of this species.

Study of the members of this genus suggests a development of the adductor platform from an impression of the adductor field to a distinct and separate plate. The intermediate in this evolution is *X. quadratus*, in which the adductor platform is slightly excavated anteriorly. This trend culminates with *X. umbonatus*, new species, in which the adductor platform is a separate plate.

The development of the cardinal process of *Xenosteges* is variable, as in other genera, but the complete story is not known. The smallest brachial valve of *X. adherens* is about 4 mm in length and that of *X. quadratus* is about 4.5 mm; neither shows

the characteristic tentlike structure of the youthful aulostegid cardinal process. The specimen of *X. adherens* is thin and delicate and, seen from the ventral side, its cardinal process is bilobed and short-shafted, surmounting a broad triangular projection that protrudes beyond the posterior margin. From the dorsal side it also presents a broadly triangular outline, the apex of the triangle serving as a lophidium, and from the posterior the cardinal process has a compressed, bilobed myophore.

The smallest specimen of *X. quadratus*, seen from the dorsal side has a slight triangular projection beyond the posterior margin, the lophidium, which, with the myophore, extend ventrally at right angles to the brachial valve. The myophore is compressed laterally and is bilobed, surmounting a short shaft. The cardinal process is bounded on each side by a swelling, or boss. Between these swellings and the dorsal side of the shell are shallow depressions. The stage described for the smallest *X. adherens* is obviously an earlier development than that for *X. quadratus*, because later stages of *X. adherens* come to resemble the condition described for *X. quadratus*.

Viewed from the posterior, the cardinal process of the adult *X. adherens* has a narrowly triangular myophore, bilobed toward the ventral side. The shaft is short and lies across a trough formed by thickened lateral ridges on the ventral side and a thin projection of the outer layer on the dorsal side. The thickened part of the palintrope bounding the delthyrium fits into the grooves on each side of the cardinal process thus formed, and the slender, narrow lophidium plugs the delthyrium. All these features are thus accessories in the articulation of the brachial valve. Adult *X. quadratus* has the same essentials as the Cathedral Mountain species, i.e., the thick lateral ridges and thin outer wall with a groove between; The lophidium is somewhat less elevated but serves the same purpose.

The myophore of the cardinal process varies from laterally compressed with a ventral groove on the shaft indicating bilobation, to widely V-shaped with the arms of the V curved laterally. Trilobation is rare.

Another feature of the cardinal process visible on numerous specimens is a growth anteriorly on the ventral side of the shaft and extending from the myophore. This forms a small cone terminating in a single point. This growth is reminiscent of the

two-coned growth on the shaft of *Edriosteges* and *Echinosteges*.

Another variable feature of *Xenosteges* is the adductor platform. In *X. adherens* it is scarcely thickened in young adults but in old shells it is fairly elevated. In *X. quadratus*, on the other hand, the adductor scars are elevated on thick platforms. The scars are elongate elliptical or tear-shaped but the anterior and posterior pairs are not well differentiated. In some specimens the rims of the outer and anterior margins of the platform are excavated. No dendritic scars have been observed in this genus.

In most adult or old brachial valves the brachial ridges are well developed or, in some species, extravagantly developed. As with the adductor platforms, the brachial ridges of *X. adherens* are generally not very prominent. In the larger and older specimens the anterior, or looped, end of the brachial ridge may be thickened and elevated slightly above the valve floor. The brachial ridges of *X. quadratus* are extravagantly developed. In some specimens they are elongated and elevated and they extend nearly to the floor of the pedicle valve. At their anterior ends they are somewhat spinose or serrate. The elevation is not confined to the anterior ends but extends to the lateral portions which connect with the elevated adductor platform. These platforms, the brachial ridges, and the brevisseptum in this species are all grown together.

### *Xenosteges adherens* Muir-Wood and Cooper

PLATE 232: FIGURES 1-48; PLATE 233: FIGURE 40; PLATE 234: FIGURES 28-32

*Xenosteges adherens* Muir-Wood and Cooper, 1960:112.

Small, rarely attaining width of 15 mm.; generally wider than long but varying from transversely rectangular to nearly square or rectangular. Hinge usually widest part; ears prominent and narrowly rounded; sides straight to sloping medially; anterior margin narrowly to broadly rounded, sulcate in old specimens. Surface nearly smooth but usually with concentric undulations concentrated on ears and sides. Rhizoid spines variable, heavier spines on outer sides; shell usually attached by beak but anchored by spines commonly attaining considerable length.

Pedicle valve strongly and somewhat narrowly convex in lateral profile; broadly convex in ante-



rior profile, with moderately sloping sides. Umbonal region narrowly convex; median region inflated; anterior slope usually steep. Sulcus, when present, originating at about midvalve, seldom conspicuous in young but strong in old specimens. Umbonal slopes steep. Ears large, rounded, well demarcated by steep lateral slope. Palintrope short; interarea short and commonly poorly developed.

Brachial valve deeply concave, greatest concavity in umbonal region, flattening and shallowing somewhat anteriorly. Ears prominent, flattened, demarcated by short but steep ridge bounding median deeply concave region. Hinge straight, fitting close to edge of pedicle valve hinge line; lophidium prominent, plugging delthyrium; cardinal process generally short-shafted.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702							
124128i	11.0	?	17.0	16.3	13.7	5.9	?
USNM 702a							
124130a	10.7	9.9	17.0	15.0	14.0	5.5	3.9
USNM 703b							
149230a	11.8	9.9	18.0	15.8	14.0?	5.5	3.4
149230b	9.9	8.1	15.0?	16.4	12.8	4.9	2.5
149230c	10.6	9.2	15.0	16.4	14.4	5.1	2.9
USNM 703a							
149229a	11.0	9.6	17.0	17.6	15.7	5.6	4.2
149229b	10.5	9.6	15.0	14.0	12.8	5.0	3.8
149229c	10.3	9.0	14.0	12.2	11.1	4.5	3.1
USNM 702b							
149228a	9.7	?	13.5	11.5	9.7	4.2	?
149228b	10.5	?	17.0	14.8	12.8	5.2	?
149228c	9.2	8.0	14.0	10.1	9.3	4.5	3.3
USNM 702							
149227a	10.5	8.6	16.5	14.9	13.6	5.4	3.2
149227b	9.5	8.2	14.0	10.1?	10.1	4.5	2.8
149227c	9.4	8.1	12.5	11.2	11.0	4.4	2.6
149227d	9.1	7.6	13.0	10.8	9.4	4.5	2.7
149227e	8.3	6.5	12.0	9.4	8.3	3.6	2.2
149227f	4.1	?	5.5	7.3	5.0	1.9	?

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation (Wedin Member), Cibolo Formation, Bone Spring Formation.

LOCALITIES.—Cathedral Mountain: AMNH 500H, 500N, 504; USNM 702, 702a, 702b, 702 inst., 702 low, 702 un, 703a<sup>1</sup>, 703b, 703bs, 708, 711q, 712o, 721u, 723k, 724r, 726o, 726u, 726x, 735b. Wedin: USNM 700-l, 700x, 714w, 717e, 723v, 727p. Cibolo: USNM 725v, 738f. Bone Spring: AMNH 660.

DIAGNOSIS.—*Xenosteges* with shell transverse in the adult, incipient adductor platform in the pedicle valve and with brachial ridges only incipiently developed.

TYPES.—Holotype: USNM 124128b. Figured paratypes: USNM 124128a, d, e, g-j; 124129a; 124130a, b. Measured paratypes: USNM 124128i,

124130a. Unfigured paratypes: USNM 124128b, c, f. Figured hypotypes: USNM 149170; 149230c, d; 154236; 154250; 154251a-d; 154248a; 154249a-d. Measured hypotypes: USNM 149228a-c, 149227a-f; USNM 149230a-c, 149229a-c.

DISCUSSION.—*Xenosteges adherens* attains a much larger size than any of the other species except *X. magnus*, new species. It is also wide in the adult stages, has prominent ears, and the greatest width is across the ears. In these respects it differs from *X. quadratus*, new species, in which the length and width are more nearly equal in the adult. Other differences from *X. quadratus* appear on the exterior as well as the interior. The interarea of *X. adherens* is usually shorter than that of the Word species. In the pedicle valve the adductor platform of *X. quadratus* is more strongly

developed and its brachial ridges are usually strongly elevated, whereas those of *X. adherens* are only slightly elevated anteriorly in adults.

The elongate form and great development of the adductor platform of the pedicle valve distinguish *X. umbonatus*, new species, from *X. adherens*.

*Xenosteges anomalus*, new species

PLATE 234: FIGURES 33–51; PLATE 244: FIGURES 38–44

Large for genus, subrectangular to semielliptical in outline, greatest width at hinge; sides varying from nearly straight to oblique anterior margin broadly rounded; ears flattened and generally small, nearly right-angled, slightly obtuse or acute; surface smooth; spines stout, usually short, few on posterior margin, umbonal region, ears, and lateral margins; all spines rhizoid. No spines on brachial valve.

Pedicle valve strongly convex in lateral profile and broadly and strongly domed in anterior profile; beak small, slightly protruded posterior to posterior margin; umbonal region narrowly swollen; median region inflated; lateral and anterior slopes steep.

Brachial valve moderately concave, anterior quarter strongly geniculated in dorsad direction, forming steep rim around sides and anterior; brachial valve deepest medially, umbonal region forming shallow pit. Ears flattened and small.

Pedicle valve interior with short, not strongly developed interarea and well-formed angular ear baffles; delthyrium open, muscle area large; adductor scars forming two parallel, elevated tracks between flabellate diductor scars. Marginal rim moderately thickened.

Brachial valve with interior structures greatly thickened in old shells; cardinal process variable, usually trilobed and moderately spreading, with well-developed lophidium but virtually no shaft developed; adductor scars thick and forming two elevated platforms in each side of brevisseptum which does not extend to cardinal process. Ear baffles forming serrated, elevated ridges and extending anteriorly as thick submarginal rim; brachial ridges elevated anteriorly and narrowly extended toward rim; strainer spines, few and thick.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	midwidth	hinge width	height	thickness
USNM 728							
154241a	10.0	9.0	17.0	12.4	11.5	5.6	2.8
(holotype)							
154241b	10.6	8.7	15.0	11.4	8.3	4.9	2.0
154241c	10.9	?	17.0	14.0	12.6	5.0	?
154941d	10.0	?	15.0	12.3	10.6		?

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway member).

LOCALITY.—AMNH 512 = USNM 728.

DIAGNOSIS.—Strongly convex, wide *Xenosteges*, with anteriorly geniculated brachial valve having a strongly thickened submarginal rim.

TYPES.—Holotype: USNM 154241a. Figured paratypes: USNM 154240a–e, 154241b–d. Measured paratypes: USNM 154241b–d. Unfigured paratype: USNM 154240c.

COMPARISON.—This is a large convex shell that need be compared only with species of similar comparable size, i.e., *X. adherens* Muir-Wood and Cooper and *X. quadratus*, new species. The former species is usually somewhat alate and has strongly

acute ears and a hinge wider than midwidth. It is also more closely attached at the umbo than *X. adherens*. The Word Formation species *X. quadratus* is more square and the interior has different details; the cardinal process is smaller, delicate, the brachial ridges are more strongly elevated anteriorly, and the anterior border is not a strongly elevated rim as in the Getaway species.

DISCUSSION.—This species is somewhat aberrant, when compared with others of the genus, especially in details of the interior. The exterior presents few features that are unusual except for the umbonal region, which appears not to have shared conspicuously in the attachment of the shell because a scar of attachment is rarely visible. Most of the

pedicle valves in the collection show no evidence of direct attachment in this region. Some have short rhizoid spines, but only one specimen showed a small flattened scar.

Inside the pedicle valve the interarea is not strongly developed and the delthyrium is spreading and not well defined. An important difference appears in the muscle scars of *X. anomalus*, which has the adductor scars attached to two elevated, elongated platforms. In *X. adherens* these scars are thickened but are more elongated than in the Getaway species and are also more closely crowded. In *X. quadratus* the scars are separated by a low myophragm and in some specimens the anterior part of the adductor platform is excavated to form an elevated plate.

The cardinal process of *X. anomalus* generally has a well-marked lophidium like that of the other species, but in one shell a clear development of a zygidium has taken place, an adaptation to a variation in the width of the delthyrium. The ear baffle of the Getaway species is strongly serrated across the ear but anteriorly it forms a solid and elevated rim around the visceral region. In this species the brachial ridges are not so strongly elevated and elongated as in *X. adherens* or *X. quadratus*. This species is rare in the upper Getaway Member of the Cherry Canyon Formation.

*Xenosteges magnus*, new species

PLATE 234: FIGURES 1-27

Large for genus, transversely rectangular in outline; widest at hinge or just anterior to hinge; sides oblique to rounded; anterior margin broadly

rounded to slightly indented. Anterior commissure with slight dorsal fold medially. Interarea short and wide, gently concave, orthocline to anacline. Surface usually of concentric lamellae, thin and scaly, often preserved only in patches, and rhizoid spines, few in number, and located on posterior margin, umbonal region, sides and ears, occasionally on body.

Pedicle valve with lateral profile moderately convex, greatest convexity near midvalve; anterior profile broadly domed with sulcate top and steeply dipping sides. Umbonal region swollen and standing above ears, posterolateral slopes steep. Median region swollen. Sulcus usually fairly strong, originating at about midvalve or slightly posterior, shallow, narrow, and causing small indentation in front margin. Anterior slope fairly long and moderately steep.

Brachial valve with median region forming deepest part, ears and cardinal extremities flattened, deflected, and separated from median concave region by fairly strong ridge or slope. Anterior dorsally deflected, with steep slope toward middle. Fold originating at midvalve, low and rounded.

Pedicle valve interior with strongly flabellate diductors and adductors separated by low myophragm. Margins thickened and flattened.

Brachial valve interior with small, short-shafted cardinal process; myophore trilobed and laterally compressed; brevisseptum short and low; adductor field elongate with lateral scars elongate triangular. Lateral ridges variably developed, usually not conspicuous; brachial ridges large but not thickened. Endospines in one or two rows, low. Anterior and lateral margins flat and smooth, often extended as short frill.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	midwidth	hinge width	thickness	height
USNM 726d							
152653a	13.2	11.4	19.0	16.4	17.1	5.1	7.0
(holotype)							
152653b	12.3	?	17.0	15.5	14.5	?	6.6
152653c	13.0	?	17.5	16.6	16.4	?	7.2
152653d	10.0	?	13.5	11.1	10.4	?	4.9
152653e	?	11.5	?	11.7	13.2	?	?
USNM 721x							
152654a	12.8	10.7	19.0	16.6	18.2	4.5	7.1
152654b	9.1	8.5	11.0	9.1	8.9	2.2	3.2

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 703a, 703c, 716x, 719x, 721j, 721o, 721x, 721y, 723a, 726d.

TYPES.—Holotype: USNM 152653a. Figured paratypes: USNM 154237; 154238; 154239a, b, e. Measured paratypes: USNM 152653b–e; 152654a, b. Unfigured paratypes: USNM 153239c, d; 152653b–e.

DIAGNOSIS.—Large, strongly convex and sulcate *Xenosteges*.

COMPARISON.—This species is most like the larger specimens of *X. adherens* Muir-Wood and Cooper, and probably descended from it. The Road Canyon species attains a larger size than the Cathedral Mountain species and is usually more narrowly umbonate and more strongly sulcate. Furthermore, the Road Canyon species has a longer interarea and a stronger fold on the brachial valve. The brachial valve interior of *X. magnus* has a more prominent development of the internal structures.

The distinction between these two species is usually one of degree. The young of *X. adherens* are usually more swollen ventrally than the young of *X. magnus* and the fully grown adult of the former is usually not so robust and has a lesser development of the fold and sulcus. The young of *X. magnus* are flattish but the brachial valves are generally more concave and the pedicle valves more strongly sulcate than those of *X. adherens*. The sulcus of the latter is variable and in many specimens it is scarcely developed. On the other hand, the sulcus of *X. magnus* is usually well developed, but a few specimens failed to develop one.

*Xenosteges quadratus*, new species

PLATE 235: FIGURES 1–60; PLATE 236: FIGURES 1–18

Shell attaining width of about 12 mm, subquadrate in outline, width of adults slightly greater than length; sides nearly straight to gently rounded; anterior margin broadly rounded. Hinge straight, variable, seldom wider than midvalve. Ears usually not well developed. Surface marked by irregular concentric wrinkles, concentrated near ears, especially on brachial valve.

Pedicle valve strongly convex in lateral profile, with anterior slope somewhat steeper than posterior one; anterior profile strongly to broadly convex, lateral slopes moderately steep; umbonal region inflated; umbolateral slopes steep, demarcated from small, swollen ears by slope change. Sulcus usually absent, obscure when present. Ears narrow, lateral extremities rounded. Interarea short; delthyrium closed by concave plate forming groove for motion of cardinal process.

Pedicle valve interior with wide, triangular adductor platform in adults; ears forming flattened area; peripheral rim thick.

Brachial valve moderately concave, deepest part in umbonal and mid regions, flattening on ears and along anterior margin. Ears flat to slightly concave.

Brachial valve interior with variable cardinal process usually short-shafted and slender but thick in some specimens; myophore varying from widely to narrowly bilobed; adductor platform thickened; brevisseptum short but strongly elevated; brachial ridges elongated and elevated above valve floor.

MEASUREMENTS (in mm).—*Xenosteges quadratus*, new species:

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706							
149195	11.0	9.2	15.0	10.4	12.0	5.5	4.8
USNM 706c							
149197	9.5	6.8	15.0	10.5	10.8	5.5	4.0
USNM 706e							
149200a	10.2	?	16.5?	11.9	12.2	6.1	?
149200b	10.6	?	18.0	10.6	12.1	5.9	?
149200c	8.6	7.6	11.0	7.9	9.0	3.3	2.1
154246a	9.3	7.0	14.0	8.4	9.6	5.0	4.4
(holotype)							



**STRATIGRAPHIC OCCURRENCE.**—Cherry Canyon Formation (Getaway Member), Word Formation (China Tank, Willis Ranch, Appel Ranch members, and lenses between the last two), Bell Canyon Formation (McCombs Member).

**LOCALITIES.**—Getaway: AMNH 21, 512, 519, 600; Moore 31; USNM 728, 730, 732. Word: USNM 732s, 737b, 741p. China Tank: USNM 706c, 713, 733q. Willis Ranch: AMNH 505, 506; USNM 706, 706e, 723t, 724u, 735c. Lenses: USNM 706b, 732c, 742b. Appel Ranch: USNM 706d, 714o, 715i, 716v, 719z, 722t, 726t, 727j. McCombs: AMNH 409.

**DIAGNOSIS.**—Squarish outline and extravagantly developed interior, especially the elevated brachial ridges characterizes this species.

**TYPES.**—Holotype: USNM 154246a. Figured paratypes: USNM 149193; 149196; 149197; 149200a, c; 154242a, b; 154243a–d; 154244a; 154245a–c; 154246b–d. Measured paratypes: USNM 149195, 149197, 149200a–c. Unfigured paratypes: USNM 149200b.

**DISCUSSION.**—This species is characterized by its nearly square outline and is thus easily distinguished from adult *X. adherens* Muir-Wood and Cooper. The extravagant development of the interior of the brachial valve of adults is another readily recognized distinguishing feature.

*Xenosteges quadratus* is generally a rare species in all of its occurrences but is commonest in a thin lens of limestone between the Willis Ranch and Appel Ranch members (at USNM 706b). It is rare in the Appel Ranch Member.

### *Xenosteges trivialis*, new species

PLATE 236: FIGURES 19–56

Small to medium for genus, subrectangular in outline, width greater than length, greatest width near hinge or slightly anterior. Sides slightly oblique to gently rounded; anterior margin gently rounded. Beak small, usually truncated by cicatrix; interarea very short, anacline. Surface with concentric undulations on ears and shell body, but not strong on anterior slope; scaly lamellae patchy. Rhizoid spines confined to posterior margin and umbo.

Pedicle valve strongly convex in lateral profile, with greatest convexity near midvalve; anterior profile somewhat narrow dome with steeply sloping sides. Umbonal region narrow and strongly

swollen, swelling continuing to anterior margin; lateral slopes steep. Sulcus completely absent. Ears prominent, strongly deflected from shell body.

Brachial valve fairly deeply concave at midvalve with fairly steep slopes to midvalve from anterior and sides. Ears deflected and flattened. Surface like that of opposite valve.

Pedicle valve interior with myophragm variably developed but with ears set off by prominent oblique ridges. Brachial valve with small laterally compressed, short-shafted cardinal process; brevisseptum low; brachial ridges slightly thickened; endospines few, usually low and thick.

**MEASUREMENTS** (in mm).—Thickness of holotype 3.1; of others, unmeasurable.

		brachial				
	length	valve length	mid-width	hinge width	height	surface length
USNM 721z						
152655a	8.7	?	10.5	11.4	4.4	14.0
152655b	8.7	?	10.2	10.6	4.5	13.0
152655c	7.9	6.3	9.6	9.6	5.0	13.0
(holotype)						
152655d	?	6.7	8.2	9.1	?	?
USNM 724c						
152656a	9.6	?	10.5	11.2	4.6	14.0
152656b	8.9	?	10.6	11.6	4.5	14.0

**STRATIGRAPHIC OCCURRENCE.**—Road Canyon Formation.

**LOCALITIES.**—AMNH 501; USNM 703, 716xa, 720d, 721z, 722e, 724c, 726e, 732j, 736x.

**DIAGNOSIS.**—Small, variable *Xenosteges* with strongly swollen pedicle valve, no sulcus and swollen umbo.

**TYPES.**—Holotype: USNM 152655c. Figured paratypes: USNM 152655a, d; 152656c–h. Measured paratypes: USNM 152655a, b, d; 152656a, b. Unfigured paratypes: USNM 152655b; 152656a, b.

**COMPARISON.**—This species is most like *X. adherens* Muir-Wood and Cooper and is entirely different from *X. umbonatus*, new species, which is elongate rather than transverse. It differs from *X. quadratus*, new species, in its less swollen form and less corrugated exterior as well as in the absence of the strongly pendant brachial ridges. It differs from small or young specimens of *X. adherens* in having a more swollen and less narrowly pinched umbonal region, stronger inner ridges defining the ears in the pedicle valve, and no trace of a sulcus on the pedicle valve or fold on the brachial valve.

DISCUSSION.—This is a variable species especially among specimens from USNM 724c. Some of them are very characteristic of the species but others tend toward flatter forms suggesting the young of *X. magnus*, new species. Furthermore, the specimens at USNM 724c tend to be smaller than those in the other localities.

*Xenosteges umbonatus*, new species

PLATE 233: FIGURES 41–62; PLATE 236: FIGURES 57–70

*Productus pileolus* Girty (part, not Shumard) 1909:270, pl. 29: figs. 5–7a.

Shell small, outline usually elongate rectangular but becoming transversely rectangular in old age; hinge generally forming widest part; sides oblique to gently rounded; anterior margin narrowly rounded. Surface marked by concentric undulations and rhizoid spines.

Pedicle valve fairly strongly convex in lateral profile, anterior and posterior slopes nearly equal; anterior profile narrowly domed. Umbo small, merging into inflated median region; lateral slopes steep and descending to swollen ears varying from small to large depending on age. Interarea short. Pedicle valve interior with broad, prominent, excavated adductor platform.

Brachial valve deeply concave medially, concavity extending from umbo nearly to anterior margin, there somewhat shallower; median concave area bounded by oblique ridges defining ears; ridges abrupt and well-defined. Ears flattened to concave, thus emphasizing bounding ridges. Brachial valve interior with prominent adductor callosity; brachial ridges abruptly elevated but short; peripheral slope steep but short; marginal groove not well developed.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 731							
149217a	10.1	?	14.0	8.0	9.4	5.6	?
149217b	8.9	?	13.5	7.2	8.6	4.9	?
159217c	7.9	?	10.5	7.0	7.1	3.4	?
149217d	10.1	8.4	15.0	6.5	9.1	5.3	3.6
(holotype)							
149217e	8.5	?	12.0	9.3?	8.3	4.3	?
149217f	9.4	?	14.0	12.3?	11.1	5.6	?
149217g	7.0	6.1	6.5	4.2	6.1	3.8	2.2
149217h	9.3	8.0	14.0	5.3	7.5	4.9	3.7
149217i	5.9	5.0	9.5	3.4	4.8	3.0	1.3

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler, Rader, and Lamar members), Capitan Formation.

LOCALITIES.—Hegler: AMNH 635; USNM 731, 732a. Rader: 725f. Lamar: 728q. Capitan: 737a.

DIAGNOSIS.—Usually elongate outline and deeply concave brachial valve but having a large adductor platform in the pedicle valve.

TYPES.—Holotype: USNM 149217d. Figured paratypes: USNM 149217a, b, f, h; 154247a-e. Measured paratypes: USNM 149217a-c, e-i. Unfigured paratypes: USNM 149217a, c, e, g, i.

DISCUSSION.—The prevailing elongate outline distinguishes this species from *X. adherens* Muir-Wood and Cooper and most specimens of *X. quadratus*, new species. It is possible that the Capitan species will prove to be the same as *X. umbonatus*,

new species, when the full range of its chracters has been demonstrated.

Subfamily CHONOSTEGINAE Muir-Wood and Cooper, 1960

Specialized Aulostegidae having posteriorly rugose and anteriorly costate shells. Anterior projecting rim in type genus bearing a row of attachment spines, brachial valve with row of anterior spines or funnels.

Genus in West Texas: *Chonosteges* Muir-Wood and Cooper, 1960.

*Chonosteges* appears in the Decie Ranch Member of the Skinner Ranch Formation and ranges into the Road Canyon Formation. In the Sierra

Diablo it occurs in the Bone Spring Formation. The genus is seldom abundant but is commonest in parts of the Cathedral Mountain Formation.

### Genus *Chonosteges* Muir-Wood and Cooper, 1960

*Chonosteges* Muir-Wood and Cooper, 1960:113.—Williams et al., 1965:H457.

Semicircular to subpentagonal in outline; hinge straight, nearly equal to midwidth; ears poorly defined; shell attached by beak and anchored by elaborate rhizoid spines on ears, umbonal slopes, and anterior margin of pedicle valve; interarea variable, usually fairly long; elytridium narrow and convex; both valves strongly geniculated. Visceral disc region of pedicle valve marked by small, rounded spine bases bearing long slender ornament spines; visceral disc region of brachial valve marked by dimples corresponding to spine bases of opposite valve; brachial valve with row of short curved tubes or erect funnels on margin. Anterior slopes of both valves costate, and anterior margins with smooth border, that of pedicle valve overlapping that of brachial valve.

Pedicle valve interior with adductor field forming narrow elevated track between diductor scars; anterior margin with row of blunt spines, each spine occupying position between costae of anterior slope.

Brachial valve interior with narrow lophidium and long-shafted cardinal process with prominent antron and bilobed or trilobed myophore. Adductor field small, moderately thickened, anterior pair of scars larger and tear-shaped; brevisseptum short, highest anteriorly but not extending beyond mid-valve; visceral disc defined by thin, high subperipheral rim bearing row of long slender spines.

TYPE-SPECIES.—*Aulosteges magnicostatus* Girty (1909:278).

DIAGNOSIS.—Anteriorly and regularly costate Aulostegidae with anterior row of rhizoid spines on pedicle valve and row of tubes or funnels on margin of brachial valve.

COMPARISONS.—This genus may be confused with *Urushtenia*, or *Strophalosiella*, neither of which has yet been found in North America. *Urushtenia* is a Russian Permian genus, strongly geniculated and with strongly costate anterior and lateral slopes but the visceral disc regions of both valves are marked by strong concentric wrinkles and the pedicle valve does not have an interarea.

*Strophalosiella* strongly resembles *Chonosteges* in outline and details of the ornament but is not provided with the elaborate row of rhizoid spines on the pedicle valve, nor with the funnels or tubes on the brachial valve. This genus seems to have been content with the smooth thickened band on the anterior of the valves, that of the pedicle valve overlapping the one on the brachial valve as in the American genus. The interior details of *Strophalosiella* are not fully known, but a cast of the interior of a specimen from Japan indicates arrangement of the muscles different from that in *Chonosteges*.

DISCUSSION.—*Chonosteges*, like most of the Aulostegidae, was attached by the beak of the pedicle valve in early growth stages. The cicatrix of attachment is variable in size and position. In some specimens the cicatrix takes up most of the umbonal slope directly anterior to the beak, but in others it occupies one or the other of the umbolateral slopes. Eccentricity of the cicatrix is fairly common.

The attachment (rhizoid) spines of this genus are of unusual interest because the shell was very securely fastened by anchor spines which are given off from all parts of the shell except the visceral disc. Young shells, before geniculation takes place, are anchored by beak ornamentation and spines from the posterior margin and the ears. After geniculation takes place and the anterior costae are initiated, spines may be given off from several points on the costae especially near the place of geniculation. After adulthood has been attained and before the anterior border is completed, the major and most important set of anchor spines is sent out. These take off from each costa on the anterior and lateral slopes just posterior to the border. These spines may be of considerable length, especially those on the anterior margin, which may have to grow for a long distance to make contact with the substrate. Anchor spines may be given off at any point along the anterior costae, apparently without plan, but are commonest near the angle of geniculation. These spines are usually short, because the pedicle valve surface is close to the substrate before geniculation takes place.

Ornament spines have a smaller diameter than the rhizoid spines, and are most abundant on the visceral disc region but are not confined to it. They also are given off from the costae of the anterior and lateral slopes but are not numerous in these areas. Ornament spines are sent off at a low angle (20°) to

the surface of the visceral disc and have a gentle curve. One specimen about 10 mm long has ornament spines 8 mm long. When *Chonosteges* is in living position, the ornament spines form a forest on the under surface and protrude from some distance between the rhizoid spines.

The most unusual adornment of this genus is the tubes or spines on the brachial valve that grow in a row around the margin from ear to ear. These may take the form of curved tubes or erect funnels, the latter evidently much rarer. From present information these tubes or funnels are not a specific character.

Forms with curved tubes are common at USNM 702un, but one unusual specimen with much expanded funnels was taken at the same locality. These structures appear at the anterior ends of the costae on the inside of the geniculated slope. In most specimens they are broken and only the proximal ends can be seen but, in the few well-preserved specimens available, the tubes extend dorsally for a short distance, perhaps a millimeter or slightly more, but then are bent anteriorly. In some specimens the bend is merely a slight inclination but in others it is more than a right angle. In such cases the tubes are actually directed posteroventrally. In a few specimens the tubes flare slightly at the distal end but in most of them no distal change in diameter is apparent. A few, however, have been noted to taper distally, but these are uncommon. The curved tubes range from 3 to 5 mm in length.

In a few specimens the tubes are upright and their distal ends flare into funnels so crowded that they have the appearance of a pipe organ. The funnels are irregular in shape, some having a stem of moderate length, others flaring directly from the end of the costa from which it extends.

The funnels or tubes are hollow throughout and open proximally into the posterior wall of the gutter formed by the smooth recurved anterior border of the shell. When the animal was in feeding position with the valves open, this gutter was full of seawater.

Although the anterior slopes of both valves are strongly costate, their margins are defined by a band that is smooth on the outside surface. The thickened smooth band on the pedicle valve attains a maximum width of 6 mm, extends from ear to ear, and is entirely smooth. It is usually a millimeter or slightly more in the direction of valve length. The costae end abruptly at the posterior edge of this

border and have the appearance of being truncated by it. This part of the pedicle valve fits into the gutter formed by the smooth anterior band of the brachial valve.

The band on the brachial valve is likewise smooth but is wider than that on the pedicle valve and fits closely over it. A gutter, or grove, is bounded by the band of the brachial valve and acts as a socket for the band of the pedicle valve. The tubes or funnels of the brachial valve open into the gutter. As explained below this gutter and the band of the pedicle valve were important to the animal in feeding.

The costae on the slopes of both valves appear anterior to the visceral disc just before geniculation. The disc area is obscurely costate on both valves. The pedicle valve is marked by the bases that bear the ornament spines, and the brachial valve is marked by shallow dimples which seem to correspond to the spine bases of the opposite valve. The spine bases are elongate but low and give the appearance of interrupted costellae. On the brachial valve the costae appear before geniculation but are usually not as strongly marked as on the anterior slope.

The palintrope of *Chonosteges* is usually well developed. It is generally a thin and delicate plate divided medially by a long and narrow delthyrium. This is closed by a delicate elytridium, well rounded, moderately elevated, and usually undistorted. Of considerable interest is the buttress for support of the palintrope built on each side near the ears. This is a callus structure, platelike in form, underneath the lateral ends of the palintrope but built medially for some distance. This extends as a curving ridge from each end of the palintrope onto the lateral wall of the valve for a short distance. These features are variously developed, strong in some specimens but poorly developed in others.

A feature of considerable interest on the inside of the pedicle valve is the row of short but needlelike spines around the entire margin. These spines are a feature of the smooth anterior rim described above. The rim of the pedicle valve fits into the gutter like margin of the brachial valve. These spines plug the openings of the tubes or funnels that open into the gutter of the brachial valve. Each spine on the anterior margin of the pedicle valve occupies a position on the smooth border opposite the groove between costae. In this way the spines fit into the holes of the funnels of the opposite valve that



occupy the ends of the costae. Inasmuch as the costae of one valve fits grooves in the other, the spines of the pedicle valve must occupy a position opposite the grooves between the costae of the pedicle valve.

Structures of the interior of the brachial valve such as the cardinal process are variable as in most of the Aulostegidae. The young cardinal process is typically aulostegid, consisting of two oblique plates that form an inverted V surmounted by a narrowly compressed, bilobed myophore. The adult cardinal process is long-shafted and usually shows the remains of the antron in the form of a deep longitudinal groove or cavity. Thus, on the ventral face the bilobed character is strongly exhibited. Some specimens show an anterior growth on this face that is reminiscent of the two-pronged callosity so strongly developed in *Echinosteges* and *Edriosteges*. This is not well developed as a rule and is generally rare.

The posterior or myophore face of the cardinal process is different from most members of the Aulostegidae in the construction of the lophidium. It is deeply excavated between the myophore and the posterior margin which protrudes conspicuously beyond the lateral ridges. The lophidium is a narrow ridge occupying this depression. It thus extends from the posterior margin to the myophore and is bounded by narrow but deep depressions. The myophore is short and usually bilobed, but some are trilobed, or even quadrilobed, and divided from the lophidium by a small curved plate (zygidium) that fits snugly against the anterior end of the elytridium. The zygidium is not developed in young specimens in which the myophore is long and narrowly compressed. In these specimens the carinate face of the cardinal process makes the lophidium, and the lateral depressed areas are not developed. In some older specimens the lateral ridges, which are not usually strongly developed in this genus, are welded to the cardinal process. In these the cardinal process, viewed from the dorsal side, appears to be broad flattened plate.

The visceral disc in old specimens is marked by a thin elevated rim that divides the flat disc from the abruptly geniculated anterior slope. The edge of this rim that faces the ventral valve is scalloped, and each tooth of the scallop is extended into a long, needlelike spine attaining a millimeter or more of length. Each spine is situated posteroventral

to the ridge separating the funnel openings in the gutter. They are thus located between the costae of the exterior. When the two valves are in contact, the spines lie along the internal grooves created by the costae of the anterior slope. In feeding gape, these spines would pull out of the funnels, allowing water to enter; when the valves closed, the spines sealed off the funnels, much as needle valves.

As mentioned above the front margin of the brachial valve is recurved in a ventral direction to form a groove bounded by a smooth outer wall. The inner wall of this groove or gutter is the corrugated surface of the anterior slope. The inner corrugations correspond to the grooves between the costae of the exterior. The costae on the outside carry the tubes or funnels but these open to the inside of the gutter at the end of the pits formed by the inner corrugations. These pits receive the spines and serrations at the margin of the pedicle valve.

The brachial ridges of *Chonsteges* are like those seen in other Aulostegidae but they are not strongly impressed, except in old individuals. The brevisseptum is short and is highest at its anterior end. The adductor field in young shells may be moderately thickened, but in old specimens the scars of the muscles may be fairly deeply impressed.

Young *Chonsteges* attaches by the beak or umbo of the pedicle valve and forms a small saucer-like body. As growth continues it becomes more nearly vertical to the surface of contact. Near adulthood the anterior parts geniculate and the shell becomes more firmly anchored. As explained under *Echinosteges*, adulthood is not a function of size: some specimens attain this state at a small size, far smaller than normal for the species, but others do not reach adult characters until they have attained their maximum dimensions.

*Chonsteges* was more elaborately safeguarded in its feeding than other Aulostegidae. The complicated set of anterior spines, gutters, and plugs is unique to this genus. The spines on the margin of the pedicle valve that are inserted into the inner opening of the tubes or funnels in the gutter of the brachial valve suggest that the funnels may have been brought into the gutter when the valves opened but the extent to which they opened must have been very small. The plugs for the funnels were possibly needed to seal the funnels against entrance by tiny predators.

*Chonosteges costellatus*, new species

PLATE 242: FIGURES 1-49

*Aulosteges magnicostatus* R. E. King, 1931:93, pl. 25: fig. 4(?).

Small for genus, wider than long, hinge usually widest; sides gently rounded; anterior margin gently rounded to nearly straight; cardinal extremities approximately right angles and with minute ears. Interarea moderately long; palintrope apsacline.

Ornamentation of pedicle valve consisting of scattered, coarse spine bases and concentric wrinkles in umbonal region, becoming costate just posterior to midvalve; anterior slope costate, costae fine and regular and separated by grooves of about same width as costae; anterior margin thickened, short, about one millimeter or less; costae numbering 28

or 30 on fully grown individual. Brachial valve pitted in posterior half but costate anteriorly; anterior margin with smooth border and gutter; outside anterior edge provided with erect funnels 2 to 3 mm long, with short, narrow stems, but gradually widening cups.

Pedicle valve with angle of geniculation nearly right angle; visceral disc region nearly flat and anterior slope nearly flat; beak and umbo small; lateral slopes steep; ears poorly defined; median sulcus variable in development, usually wide and shallow, slightly indenting the anterior margin. Pedicle valve interior not seen.

Brachial valve nearly flat except for geniculation which is short and deep; median region slightly concave. Brachial valve interior with massive cardinal process for small shell; adductor field fairly large, scars with slightly thickened rims. Brachial impressions lightly impressed.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	maximum width	height	thickness
USNM 703a <sup>1</sup>							
149275a	11.3	8.7	19.0	12.0	13.6	7.0	5.8
149275b	8.9	8.0	15.0	10.8	12.0	5.4	3.9
149275c	10.6	8.2	17.0	10.0	11.8	6.4	4.9
149275d	11.5	9.3	18.0	11.4	12.9	7.0	4.3
149275e	10.7	9.0	16.0	14.0	14.6	5.9	3.3
149275f	8.8	8.0	15.0	10.0	11.8	5.3	3.8
149275g	8.8	8.0	13.5	8.5	11.0	4.9	2.9
USNM 726o							
152661a	11.9	8.7	19.0	13.9	14.5	7.2	4.4
(holot)							
152661b	11.4	10.0	17.5	12.5	14.4	7.0	4.6
152661c	10.5	9.3	16.0	13.0	13.0	5.6	3.8

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation, Road Canyon Formation.

LOCALITIES.—Cathedral Mountain: USNM 702, 702un, 703a<sup>1</sup>, 703b, 712o, 723k, 726o, 726u. Road Canyon: 702c, 703a, 721r, 721x.

DIAGNOSIS.—Fairly convex, small to medium size, with fine and regular costae.

TYPES.—Holotype: USNM 152661a. Figured paratypes: USNM 149275e, f; 154168a-e; 154169a-h; 154170a, b. Measured paratypes: USNM 149275a-g; 152661b, c. Unfigured paratypes: USNM 149275a-d.

COMPARISON.—*Chonosteges costellatus* is most likely to be confused with some forms of *C. variabilis*, new species, especially those with finer costel-

lae than usual for the species, it is generally a more convex species than *C. variabilis*, and it is also characterized by a slight but unmistakable median sulcus that forms a sinuation or flattening of the median region. This is generally not seen in the other species.

Generally larger size and stronger costae separate this species from *C. magnicostatus* (Girty). *Chonosteges limbatus*, new species, is usually somewhat smaller than *C. costellatus* but differs in having the strong anterior band and in a more convex lateral profile. *C. multicostatus*, new species, is totally unlike *C. costellatus*.

*Chonosteges costellatus* is not widely distributed either geographically or stratigraphically. It is

known only from the upper part of the Cathedral Mountain Formation, in which it occurs commonly with *Collemataria* in a zone just under a bed abounding in *Edriosteges*. Specimens from the *Edriosteges* beds at the base of the Road Canyon Formation are also referred to this species.

***Chonosteges limbatus*, new species**

PLATE 240: FIGURES 1–14

Small for genus, wider than long, hinge widest, or slightly narrower than midwidth; sides gently rounded; anterior margin broadly rounded; cardinal extremities acute to narrowly rounded. Pedicle valve with widely scattered ornament spines; costae originating on geniculated slope, numbering 24 on large specimens, and anterior band exceptionally long. Brachial valve with anterior band of usual length.

Pedicle valve with geniculation near right angle or slightly greater; visceral disc region slightly swollen; lateral slopes moderately steep; sulcus perceptible in few specimens. Brachial valve gently concave, greatest concavity in midregion.

Interior details not known.

MEASUREMENTS (in mm).—From locality USNM 702d, specimen 149285a (holotype): length 10.0, brachial valve length 8.0, surface length 17.5, hinge width 11.9, maximum width 12.1, height 6.3, thickness 4.5.

STRATIGRAPHIC OCCURRENCE.—Hess Formation (Taylor Ranch Member), Skinner Ranch Formation (top, and Poplar Tank Member), Bone Spring Formation.

LOCALITIES.—Taylor Ranch: USNM 702d, 702e; Skinner Ranch: USNM 707, 723s, 733j, 739g. Poplar Tank: USNM 741k. Bone Spring: AMNH 492, 634; USNM 728g.

DIAGNOSIS.—*Chonosteges* usually of small size, having a long front border.

TYPES.—Holotype: USNM 149285a. Figured paratypes: USNM 154156a, b.

DISCUSSION.—This species is distinguished from all others in the Glass Mountains by its small size and the great length of the anterior border. The latter feature is variable, because the younger specimens are not provided with an exceptionally long border, but the adult forms are usually striking in this respect. This species was collected in silicified condition only in the "Fossil bed" of P. B. King, where it occurs in the sponge reef at USNM

702d. It is probable that specimens taken at USNM 702e, where sponges are rare, were dead shells that originally lived among or on the sponges. In any case, the species is uncommon.

***Chonosteges magnicostatus* (Girty)**

PLATE 244: FIGURES 1, 2

*Aulosteges magnicostatus* Girty, 1909:278, pl. 31: figs. 4, a, b.

The type specimen of this species is so poor and so unusual that reference of other specimens to it is very uncertain. The specimen is small and longer than wide, an unusual feature for normal specimens of this genus, which are generally wider than long. Furthermore, the interarea is about 2 mm long, an unusual length for such a small specimen of the genus. Nineteen costae can be counted along the margin, but this is not the total number because at least one on the left side cannot be seen and those in the vicinity of the left ear are covered by matrix. The specimen probably has 24 costae.

Among the numerous collections of *Chonosteges* available for study we are unable to find any that compare favorably with this specimen. The vast majority of specimens are wider than long, unless obviously distorted by living under inhospitable conditions. Girty's type specimen is the only one he had. Furthermore, the locality USGS 3840 (green) and zone from whence it came are unknown. Its location is given as "Delaware Mountain Formation, mountains northwest of Marathon, Texas." It is thus impossible, at present, to get any help from either paleontology, geography, or stratigraphy in making the status of *C. magnicostatus* more certain.

TYPE.—Holotype: USNM 118548.

***Chonosteges matutinus*, new species**

PLATE 240: FIGURES 15–33

Small for genus, slightly wider than long, outline subrectangular; hinge equal to or slightly wider than midwidth; sides gently rounded and slightly oblique; anterior margin broadly rounded. Interarea moderately long, elytridium long, narrowly convex. Beak fairly long in some specimens. Costellae numbering 22, broad, rounded, crowded and with narrow interspaces. Spines not preserved.

Brachial valve strongly geniculated in lateral profile, posterior half behind geniculation, flat or flatly convex, but anterior or geniculated half, flat-

tened to moderately convex. Umbonal region moderately swollen; ears deflected, small.

Pedicle valve mostly flat, umbonal region elongate, swollen; concentric lamellae and pits strong; geniculated part costellate.

Interiors unknown.

MEASUREMENTS (in mm).—Thickness of holotype 2.6, of other specimens, unmeasurable.

	brachial			hinge	height	surface
	length	valve length	mid-width			
USNM 707a						
149307a	7.3	?	8.0	10.6	3.2	13.0
149288a	7.8	?	7.9	9.0?	4.0	12.0
149288b	8.2	6.8	8.7	10.5	4.0	12.0
(holotype)						

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch Member.)

LOCALITIES.—USNM 707a, 727u.

DIAGNOSIS.—Small, strongly costellate *Chonosteges*.

TYPES.—Holotype: USNM 149288b. Figured paratypes: USNM 149307a, b; 149288a. Measured paratypes: USNM 149307a, 149288a.

COMPARISON.—This species needs to be compared only with *C. limbatus*, new species, which is the next largest of the species described here. The Decie Ranch species differs in having the length and width more nearly equal, in having slightly less costellae, and in having a narrower band at the anterior in the adult.

DISCUSSION.—Our extensive collecting in the Decie Ranch Member resulted in the acquisition of only eleven specimens of this species. It is also the lowest level at which the genus was taken.

*Chonosteges multicostatus*, new species

PLATE 240: FIGURES 34-51

Large for genus, wider than long, wide hinge equal to or slightly less than greatest valve width just posterior to midvalve. Sides nearly straight to gently rounded; anterior margin broadly rounded; interarea moderately long.

Ornamentation of pedicle valve fine in details, with visceral disc covered by numerous fine concentric wrinkles bearing small nodes with long hair-like ornament spines. Ornament spines confined to visceral disc and posterior part of anterior slope; geniculated area and anterior slope costate, costae slender and crowded, about 36 on large specimens; spaces between costae narrower than costae, ter-

minating in small but deep pit. Anterior border short. Brachial valve with entire visceral disc marked by fine concentric wrinkles, uneven and discontinuous and pitted by small dimples. Anterior border longer than on pedicle valve but short, measuring about 1.5 mm in large specimens. Outer edge of border provided with row of large, narrow-stemmed rapidly enlarging funnels having length of about 3 mm and maximum diameter of 1.5 mm.

Pedicle valve strongly geniculated, visceral disc gently inflated in lateral profile; anterior slope nearly flat in profile; anterior profile broadly domed but flattened on top, sides steeply sloping. Ears small. Beak small forming an angle of about 110° to 120°.

Brachial valve nearly flat but umbonal region forming shallow concavity nearly to midvalve; ears slightly depressed and flattened. Brachial valve interior with large and wide cardinal process; moderately thickened adductor field and elevated bladelike brevisseptum. Subperipheral rim thickened and strongly elevated laterally but depressed low medially.

MEASUREMENTS (in mm).—From locality USNM 703bs specimens 149301c (holotype) and d, respectively: length 11.0, 13.3; brachial valve length 9.9, 10.5; surface length 14.5?, 22.5; hinge width 14.0, 16.4; maximum width 14.9, 17.4; height 5.2, 7.9; thickness 3.9, 5.1.

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITY.—USNM 703bs.

DIAGNOSIS.—Large *Chonosteges* with numerous fine costae and with large, erect funnels on the brachial valve.

TYPES.—Holotype: USNM 149301c. Figured paratypes: USNM 149301a, b, d-f. Measured paratype: USNM 149301d.

DISCUSSION.—This species is characterized by its large size and fine costae. In size it is equal to about the largest of the specimens of *C. variabilis*, new species, but can be readily distinguished from that species by the much finer costae. It also differs from *C. variabilis* in being proportionally wider, and the anchor spines, in conformity with the fineness of the costae, are more slender and delicate.

*Chonosteges multicostatus* suggests *C. magnicostatus* (Girty) which is likewise finely costate and has erect funnels on the brachial valve but no specimens of the latter have been seen that even approach the size of *C. multicostatus*. Proportionately



thicker anchor spines characterize *C. magnicostatus*. No confusion is likely between *C. multicostatus* and the other known species of *Chonosteges*, because none of these attain the large size nor are they as numerous as *C. multicostatus*.

*Chonosteges multicostatus* is known from a single locality only, where it occurs with *Agelesia triangularis* (R. E. King), which is abundant there. At this place, which appears to be a local bioherm with its own peculiarities, *Chonosteges* is rare, and so are all other species except *Agelesia triangularis*.

***Chonosteges pulcher*, new species**

PLATE 241: FIGURES 1-52; PLATE 244: FIGURES 3-22

About median size for genus, wider than long, maximum width near midvalve; hinge wide and straight, usually slightly less than greatest valve width; cardinal extremities usually slightly greater than right angle, narrowly rounded, sides gently rounded; anterior margin broadly rounded. Palintrope usually apsacline; interarea moderately long.

Pedicle valve with geniculation slightly less than right angle; lateral profile unequally convex, visceral disc gently convex, geniculated area narrowly but strongly convex, anterior slope gently convex. Anterior profile broadly convex, maximum elevation of profile gently rounded to flattened. Lateral slopes steep; beak small, commonly elongated and misshapen; sulcus shallow, wide, seldom prominent, confined to anterior slope.

Pedicle valve ornament on umbo and umbonal slopes consisting of elongate pustules bearing ornament spines, pustules cancellated by concentric undulations; visceral disc anteriorly costate and partially cancellated by concentric undulations; anterior and lateral slopes costate, costae numbering 28 at maximum; costae narrowly rounded, steep-sided, interspaces equal in width to costae or slightly wider. Costae ending on smooth band with surface at slight angle to valve surface, giving illusion of underlying costae. Length of band (measured in line with length of shell) 1 mm or slightly more. Anterior edge scalloped, each high point bearing long, needlelike spine. Pedicle valve interior with only slight thickening across ears and modest development of adductor track.

Brachial valve nearly flat or perceptibly concave; umbonal region frequently concave; angle of geniculation abrupt; surface intricately marked by cancellated concentric undulations and radial costae complicated by dimples corresponding to spine-bearing pustules of opposite valve; costae appearing near midvalve. Anterior gutter deep and narrow; anterior band variable, attaining length of 2 mm but usually narrower. Outer edge of gutter provided with blunt spines commonly closed to exterior, but few specimens with scattered narrow open tubes or longer closed spines. No elaborate funnels seen, majority of specimens with closed spines.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	maximum width	height	thickness
AMNH 504							
149294	11.3	8.5	20.0	12.8	13.8	7.4	4.4
(holotype)							
USNM 714w							
149279a	8.4	7.6	3	11.2	11.8	5.2	3.8
149279b	9.4	7.9	14.0	11.2	11.2	5.0	3.0
149279c	8.7	7.5	14.0	10.3	11.3	5.1	3.3
149279d	9.5	7.0	12.0	9.6	10.1	3.4	2.8
USNM 717e							
149280a	10.7	?	20.0	14.9	15.2	6.7	?
149280b	8.0	7.6	16.0	11.7	12.2	5.5	3.7
149280c	9.8	8.2	15.0	10.9	11.6	5.4	3.6
USNM 708							
149276a	9.4	7.8	13.0?	10.6	11.6	4.6	2.8
USNM 725v							
152662a	11.0	?	15.0	13.2	13.2	4.7	?
USNM 727p							
154164b	10.0	9.0	16.0	11.5	13.0	5.5	3.5

**STRATIGRAPHIC OCCURRENCE.**—Cibolo Formation, Bone Spring Formation, Cathedral Mountain Formation (Wedin Member).

**LOCALITIES.**—Cibolo: USNM 725v. Bone Spring: AMNH 660. Cathedral Mountain: AMNH 500, 504; USNM 702, 708, 712o, 714w, 721u, 723u, 726o, 726u, 727q, 731b. Wedin: USNM 700-l, 700x, 717e, 723v, 727p; Moore 23.

**DIAGNOSIS.**—Small to medium *Chonosteges* having about 28 costae and provided with erect funnels on the brachial valve.

**TYPES.**—Holotype: USNM 149294. Figured paratypes: USNM 149280b, c; 154157a–g, i, l; 154163a–d; 154164a–c; 154165a–d; 154166; 154157a. Measured paratypes: USNM 149276a, 149279a–d, 149280a–c, 152662a, 154164b. Unfigured paratypes: USNM 149280a; 154157h, j, k.

**DISCUSSION.**—Because of the finely costate exterior of this species it is directly comparable only to *C. costellatus* and *C. multicostatus*, new species. It is generally smaller and proportionally finer ribbed than *C. costellatus* and is smaller and much differently proportioned than *C. multicostatus*, which geniculates at a point about 10 mm from the beak. *Chonosteges pulcher* geniculates about half this distance from the beak.

*Chonosteges pulcher* is not common. It occurs with *Institella* in the western part of the Glass Mountains on the Decie Ranch, on the north flank of Dugout Mountain, and in a fault block (USNM 708) on the Hess Ranch. In the latter of these places it is rare but is fairly common in the exposures on the Decie Ranch.

### *Chonosteges variabilis*, new species

PLATE 212: FIGURES 1–10; PLATE 243: FIGURES 1–21; PLATE 245: FIGURES 1–16?, 17–38

*Aulosteges magnicostatus* King (not Girty), 1931:93, pl. 25: figs. 1–3.

*Chonosteges magnicostatus* Muir-Wood and Cooper (not Girty), 1960:113, pl. 20: figs. 1–9; pl. 21: figs. 1–6.

Large for genus, plano-convex, subsemicircular in outline; hinge straight, variable, normally widest part of shell but frequently distorted; cardinal extremities narrowly rounded or angular, nearly at right angle; sides gently curved and usually sloping

slightly toward the midline. Anterior margin broadly rounded to nearly straight medially. Cica-trix small to large, frequently off-center. Interarea variable, usually short.

Ornamentation variable, visceral disc of pedicle valve marked by small, elongate spine bases bearing long ornament spines, arranged in quincunx. Posterior two-thirds of visceral disc area of brachial valve marked by shallow dimples. Ornament spines more distantly arranged on anterior slope but confined to costae; all ornament spines given off at low angle to shell surface (20°). Costae originating on pedicle valve at angle of geniculation, narrowly rounded and separated by grooves about as wide as costae; number of costae variable, average-sized individuals having about 24, but as many as 30 on exceptional specimens. Costae appearing on anterior third of brachial valve. Anterior smooth, border usually short (in relation to the valve length) in both valves, usually 1 mm or slightly more, but much longer in unusual specimens.

Brachial valve with row of tubular spines attaining length of 4 mm, curved over anterior margin and directed posteroventrally. Rare specimens with erect funnels.

Pedicle valve with uneven lateral profile, visceral disc region generally slightly to moderately convex; geniculated part narrowly convex and occurring at about two-thirds valve length from beak; anterior slope steep, angle of geniculation about 85°. Anterior profile broadly convex, median region somewhat flattened, sides sloping steeply. Beak small; umbonal region narrowly convex but merging abruptly into general convexity of visceral disc region. Ears inconspicuous; sulcus usually obsolete, shallow in small percentage.

Brachial valve flat to gently concave to point of geniculation, there bent at angle of about 85°. Trail steep, longest at midvalve, descending posterolaterally; ears poorly defined, flattened.

Pedicle valve interior with moderately thickened adductor field; moderately developed callus supports to palintrope; marginal spines moderately long. Brachial valve interior variable, commonly moderately thickened, usually showing remnant of antron; adductor field moderately thickened or deeply impressed in old shells; brachial ridges rarely well-developed; submarginal rim usually well formed, with long spines, most elevated laterally but shorter medially where rim is low and sulcate.

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	maximum width	height	thickness
USNM 703a							
149252a	14.6	?	20.5	19.8	20.6	6.7	?
149252b	13.8	11.7	20.0	13.4	16.2	6.7	4.3
USNM 702b							
149257a	11.3	9.4	17.5	13.8	14.3	6.2	3.3
149257b	10.2	8.1	16.0	11.9	13.0	5.8	3.7
149257c	11.2	8.9	16.5	9.7	11.3	5.0	3.9
USNM 702un							
149259a	11.4	10.0	18.5	13.6	15.0	6.5	4.7
149259b	11.8	9.1	18.0	10.8	13.5	6.5	4.5
149259c	10.3	8.1	15.0	11.9	12.5	5.5	3.9
149259d	9.6	7.3	12.5	9.5	10.6	3.4	3.0
USNM 702a							
149251a	13.8	10.6	24.0	13.8	16.0	8.2	6.0
149251b	10.2	8.6	16.0	9.8	12.8	5.7	3.0
149251c	10.5	9.1	17.0	12.0	13.1	?	4.5
149251d	11.4	8.4	14.5	10.9	12.3	5.3	4.1
149251e	10.7	8.1	14.0	10.7	11.4	4.6	2.9
149251f	9.3	8.1	13.0	10.9	11.4	4.8	3.3
149251g	8.6	6.8	13.5	9.5	10.8	5.0	3.3
149251h	9.7	6.5	13.5	4.4	7.1	4.4	3.4
149251i	8.9	6.8	11.5	8.0	9.0	3.4	2.4
149251j	7.6	6.9	9.0	6.4	8.4	2.8	2.3
149251k	6.7	6.1	7.0	6.4	8.1	2.3	2.0
149251-l	11.7	9.0	21.0	11.3	13.2	7.7	6.0
124133b	13.6	10.2	?	10.4?	15.9	7.0	6.3
(holotype)							

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation, Skinner Ranch Formation (Decie Ranch, Poplar Tank, Dugout Mountain, and Sullivan Peak members), Cathedral Mountain Formation.

LOCALITIES.—Bone Spring: AMNH 492, 591, 696. Decie Ranch: USNM 707a, 707g. Poplar Tank: USNM 707ha, 708e. Dugout Mountain: 700o, 700t, 732e, 733-l. Sullivan Peak: USNM 707b, 707d, 718z, 722h, 722-l, 727a. Skinner Ranch (lower): USNM 711d, 712p, 720f. Skinner Ranch (upper): USNM 705r, 709, 709a, 709z, 710r, 711z, 723-l. Skinner Ranch: USNM 727m, 730s. Cathedral Mountain: AMNH 500A, 500C, 500J, 500L, 500M, 504; USNM 702, 702a, 702b, 702ent, 702-low, 702un, 703b, 710d, 711q, 714w, 721u, 723u, 723y, 726o, 726u, 726x, 726y, 727x, 731t, 733m, 735b.

DIAGNOSIS.—Strongly costellate *Chonosteges* of medium to large size with stout anchor spines and curved pipes or rarely funnels on the margin of the brachial valve.

TYPES.—Holotype: USNM 124133b. Figured paratypes: USNM 123901; 123902; 124131a; 124132a, b; 149251; 149259a, b; 154153b, c; 154154a, c-d, g-i;

154155; 154158a, b; 154384; 154385. Measured paratypes: USNM 149251a-l; 149252a, b; 149257a-c; 149259a-d. Unfigured paratypes: USNM 123903c; 124131b; 154163a; 154154b, e, f. Figured specimens: USNM 149264; 154159a, b; 154160; 154161.

COMPARISON.—This species is variable in all respects, in outline as well as in costation. Some specimens appear to conform fairly well to *C. costellata*, new species, but the majority have stronger costellae than that species. The strong costellae distinguish this species from all others described here. Along with the strong costae go the stout and thick anchor spines that spring from them and form the row around the anterior margin of the pedicle valve.

DISCUSSION.—A feature still more striking than the coarse costellae is the bent tubes around the anterior margin of the brachial valve. This is the only species in which these have been seen. They contrast strongly with the erect funnels of *C. multcostatus*, and *C. pulcher*, both new species. Several specimens of *C. variabilis* also have erect funnels but, even allowing for difficulties in preservation and recovery from siliceous residues, they are very

rare. The specimens with funnels come from the same blocks taken at USNM 702un that produced the numerous individuals with curved tubes. A specimen with bent tubes was taken also from the Skinner Ranch Formation (USNM 711).

The Skinner Ranch Formation has yielded specimens of *Chonosteges* but none abundant. The result is that most of the specimens are here referred to *C. variabilis* although some of them seem atypical. They are generally more strongly costellate than the other species and seem to fit into the variable *C. variabilis*. Larger collections may ultimately crystallize the few differences and make it possible to identify other species from these lower stratigraphic horizons.

### Subfamily INSTITELLINAE Muir-Wood and Cooper, 1960

Aulostegidae having trails forming a large anterior gutter, with tonguelike extension in the pedicle valve. Ornament costellate and visceral disc reticulate. Brachial valve without spines.

Genera in West Texas: *Institella* Cooper, 1942; *Glyptosteges*, new genus; *Craspedona*, new genus.

*Institella* makes a zone across the mountain and marks the base of the Cathedral Mountain Formation. We did not find the genus outside this formation. It is known however in the Caucasus and in the Sosio Formation of Sicily.

*Glyptosteges* characterizes the Skinner Ranch Formation, especially the Dugout Mountain Member (Second Limestone Member of the Leonard Formation of P. B. King). It is not common anywhere and is difficult to obtain because of its fragile shell. Its habit of attachment was like that of *Institella*.

### Genus *Institella* Cooper, 1942

*Institella* Cooper, 1942:230.—Muir-Wood and Cooper, 1960: 117.—Williams et al., 1965:H458.

Subrectangular outline, convex pedicle valve, but nearly flat to gently concave brachial valve; anterior commissure strongly folded toward brachial valve; pedicle valve deeply and narrowly sulcate; both valves provided with elaborate frill directed ventrad; surface of both valves costellate; surface of visceral disc area fairly regularly concentrically wrinkled to produce reticulate pattern suggesting

dictyoclostids. Rhizoid spines long and stout, located on ears, posterior margin, and umbo; ornament spines rare; brachial valve without spines.

Pedicle valve with short interarea, no elytridium; margin of visceral region sharply keeled; diductor scars flabellate; diductor field narrowly elevated on ridge formed by exterior sulcus; inner adductor scars long and narrow, outer scars small, dendritic.

Brachial valve with prominent lateral ridges, sessile cardinal process, and delicate, elevated breviseptum; adductor field small, moderately elevated with inner scars smooth but outer scars dendritic.

TYPE-SPECIES.—*Productus leonardensis* R. E. King (1931: 70, pl. 14: figs. 4–9).

DIAGNOSIS.—Costellate-reticulate, frilled Aulostegidae having strongly uniplicate anterior commissure.

TYPE-SPECIMEN.—King did not name a holotype but mentions his figure 5 as a cotype. In his list of localities from which this species was taken he uses the word "types" after locality 120. He also gives the same locality for three of the measured specimens. Presumably he regarded the specimens from this place as typical of his species. Unfortunately he figured only one of them; it appears to be incomplete and is illustrated from the side only. This specimen (YPM 10706) is therefore chosen as lectotype of the species.

COMPARISON.—The only genus having external similarity to *Institella* is *Sinuatella* from the Mississippian of Great Britain. The British genus is not provided with the elaborate flange of the Permian genus and the interior details of both valves are different. The Mississippian genus in the pedicle valve has a strongly impressed muscle-area having the shape and strength of muscle impressions different from those of *Institella*. Inside the brachial valve the lateral ridges of *Sinuatella* are not so prominent and the outer adductor scars are not dendritic. Externally, *Institella* is similar to *Craspedona* but differs in exterior and interior details, as related under *Craspedona*.

DISCUSSION.—Many features of *Institella*, such as its leptaenoid form, obscure its relationship to the Aulostegidae. In spite of this the collection includes many specimens showing the members of this genus to have been attached and to have had the living habits of the Aulostegidae.

EXTERIOR.—The exterior of this genus is unusual for its ornament, and for the fold, sulcus, and frill.



The ornament is unusually strong for a member of the Aulostegidae and the reticulation of the visceral region suggests relationship to the Dictyoclostidae. Aulostegid characteristics are too strong, however, to permit classification with that group. It is a clear case of duplication of ornamental features in unrelated stocks, a phenomenon that helps to cloud brachiopod systematics.

In most productids the fold and sulcus are not well developed. In *Institella*, however, the sulcus is so deep and narrow that it divides the pedicle valve into two halves and the crease on the outside is reflected on the inside as a high and effective median ridge. Anteriorly, the sulcus appears at the anterior end of the pedicle valve as a narrow trough in the frill, almost a tube in extreme cases. The sulcus originates on the umbo of the pedicle valve and deepens anteriorly to the front margin.

On the brachial valve the fold is correspondingly well developed. The umbonal region forms a deep, nearly circular pit. At the anterior end of this pit the fold originates as a low ridge which elevates anteriorly and in most specimens is fairly strongly carinate. At the anterior end in well-preserved specimens the fold is also prolonged into a tubular arrangement fitting closely over that of the opposite valve. Usually this is broken away and the fold produces an angular notch at the anterior end.

The lateral and anterior frills are the most characteristic feature of this peculiar genus. They are well developed on both valves but are usually best preserved on the pedicle valve. In well-preserved specimens the frill grows abruptly in a ventral direction at an extremely small angle. It grows ventrally to a plane almost level with the surface of the median swollen flanks of the pedicle valve. It then flattens and grows laterally for a considerable distance to form a broad expansion. In the older specimens it then changes growth direction to dorsal and forms a gutter around the inside of the frill. Thus the body of the shell is surrounded by a deep moat produced by the frill, and the interior is surrounded by a gutter formed of the inside of the frill and bounded by its dorsally growing rim. At the anterior end of the valve, where the sulcus meets the margin, the frill is narrowly folded anteroventrally to form a deep trough or half-tube. When viewed from the inner side, this forms a carinate ridge or apex to the frill. The boundary between the interior and the lateral slope of the frill is almost knife-edge

sharp. A frill closely fitting into the one of the pedicle valve is formed by the opposite valve. This one does not always match the other in development especially at the anterior end. These deep gutters on each side of the valve are undoubtedly devices to help channel the incoming water currents in feeding. These probably ran along the steep sides of the pedicle valve gutter and entered near the ears. The semitubular anterior end probably served as the outlet for waste-bearing currents.

SPINES.—As in most of the Aulostegidae two types of spines appear on *Institella* but an unusual feature of the genus is the poor development of ornament spines. These appear rarely on the visceral disc region and are given off from the points, or nodes, formed by intersection of the concentric wrinkles and the costellae. No specimen in the collection preserves these well enough to show their true length. The bases are small and it is therefore supposed that the spines were short.

The rhizoid spines are strong and are confined to the ears, umbo, the posterior margin, and the frill to about midvalve. In the very young, rhizoid spines appear on the umbonal slopes as well. Some large specimens have rhizoid spines 4 to 5 inches long. These weave along the various surfaces of attachment and must have made strong and effective anchors. Some of the spines, however, were of no advantage to their owner. In one instance a spine extends from the posterior line for a half inch then turns abruptly onto itself, where it cements to its own visceral disc surface and runs along it for a considerable distance, affording no support or anchoring.

PEDICLE VALVE INTERIOR.—The interarea of *Institella* is usually short and the delthyrium open. In some specimens the same type of concave plate appears in the apex of the delthyrium as that seen in *Limbella*. This is a small concave callosity which serves as a socket in which the lophidium of the cardinal process revolves.

The diductor scars of *Institella* are broad and flabellate, occupying about the posterior half of the valve on each side of the carinate median elevation formed by the sulcus. The adductor field is long and slender, and the median scars are perched on the crest of the median ridge. These are long and slender, with evidence of another lateral lobe, suggesting a form like that of *Edriosteles*. Posterior and posterolateral to these muscles is a pair of

strongly dendritic scars. In large, old specimens the anterior set becomes dendritic.

**BRACHIAL VALVE INTERIOR.**—The cardinal process is the most important interior feature of *Institella*. It is typically aulostegid in being a tent-shaped structure with deep pit facing ventrad. Unlike *Edriosteges*, *Limbella*, and *Echinosteges* it is rather flat apically. The small *Institella*, about 5 mm long, is deeply concave, especially in the posteromedian region. Specimens about 8 mm in length are less concave but the posterior region is nevertheless fairly swollen. In specimens of this size the cardinal process is still deeply excavated, and the thickening elongate adductor tracks form a groove leading into the cardinal process antron. Filling of the antron has already started in specimens 12 to 13 mm in length. In specimens 15 to 20 mm long the antron is nearly or completely filled. In most larger and thicker specimens the antron has completely disappeared. In some specimens the two prongs so characteristic of *Edriosteges* and *Echinosteges* are present, although generally rare.

The shaft of the cardinal process of *Institella* is so short as to appear nonexistent in old specimens. Furthermore, the bowed lateral ridges join the sides of the cardinal process so intimately that the two structures appear as one. The myophore of the cardinal process shows the same variations as in other aulostegid genera, some specimens having a widely bilobed process, others are tightly trilobed, and still others are widely trilobed. In young specimens the myophore is generally bilobed when viewed from the ventral side and either bilobed or trilobed in posterior view. The lophidium of the cardinal process is always prominent and strongly carinate. It forms the sole closure to the delthyrium.

Variation in the cardinal processes of *Institella* appears to be completely random, as in other aulostegid genera. Small specimens may exhibit completely adult characters, while others of larger size still preserve juvenile features.

The brachial ridges in this genus are somewhat better preserved than in *Echinosteges*, *Edriosteges*, and *Limbella*. The ridge starts between the smooth and dendritic diductors, then slopes anterolaterally to make a narrow loop on the swollen flank.

The adductor field is somewhat elongated and consists of an anterior or inner pair of scars, each scar lobed, with the larger one inside flanking the brevisseptum and the smaller one on the outside.

These are flanked on the outside and posterolateral to the inner pair by a dendritic pair of scars. The pattern is thus like that of *Edriosteges* and related genera.

**STRATIGRAPHIC OCCURRENCE.**—*Institella* is a common genus only in the Glass Mountains and is here restricted to a certain part, the Cathedral Mountain Formation. It is rare in the western part of the mountains, where it occurs in abundance only in the Wedin Member of the Cathedral Mountain Formation. In the eastern part of the mountains it is common in the vicinity of Split Tank but is rarer elsewhere. *Institella*, in our experience, appears first in the thin limestone interbedded with yellow shales at the very crest of Leonard Mountain. Although it has been reported outside of these levels, we have not collected it from any other horizons.

Elsewhere in the United States the genus occurs in the middle part of the Cibolo limestone in the Chinati Mountains at the narrows of Cibolo Creek and in the upper part of the Bone Spring Formation and Victorio Peak Member.

Outside the United States Licharew (1937:58) assigned to *Sinuatella* his species *Productus sub-sinuatus*, but the strong folding, large frill and fine, reticulate ornament suggest *Institella*. These specimens come from the P<sub>b</sub> level of the Permian in the North Caucasus.

Two species are also known from the Sosio beds of Sicily. *Productus salomonensis* Gemmellaro (1892:26) (USNM 149167) is a large species suggestive of *I. leonardensis* (King) but has a less angular sulcus, more ornament spines, and finer ornamentation. Another species (USNM 149165, 149166), not named so far as we know, is smaller, more strongly ornamented, and has a shallower and narrower sulcus than *I. salomonensis*.

### *Institella leonardensis* (R. E. King)

PLATE 246: FIGURES 6–14; PLATE 247: FIGURES 1–31; PLATE 248: FIGURES 1–38; PLATE 463: FIGURES 1–4; PLATE 468: FIGURE 10

*Productus leonardensis* R. E. King, 1931:70, pl. 14: figs. 4–9.—

Cooper in Shimer and Shrock, 1944:351, pl. 138: figs. 3–5.  
*Institella leonardensis* (R. E. King) Muir-Wood and Cooper, 1960:117, pl. 22: figs. 1–15.

Shell attaining width of about 50 mm, subrectangular in outline, length greater than width;

frilled adults with gently rounded sides and deeply sulcate anterior margin; young nonfrilled specimens with gently rounded sides and broadly rounded anterior margin; anterior commissure

strongly uniplicate. Hinge equal to or somewhat less than widest part at or near midwidth. Surface of both valves with 6 to 9 costellae per 5 mm at the front. Visceral region of both valves marked

MEASUREMENTS (in mm).—

	<i>length</i>	<i>brachial valve length.</i>	<i>surface length</i>	<i>hinge width</i>	<i>width without frill</i>	<i>maximum width</i>	<i>height</i>	<i>thickness</i>	<i>frill length</i>
USNM 702b									
149163a	33.1	?	46.0	27.0?	27.0	50.5	11.4	?	8.0
149163b	28.9	16.7	35.0	28.0	23.0	39.7	9.2	6.8	8.0
149163c	30.3	29.0	45.0	25.0	27.0	42.3	11.5	8.5	7.5
149163d	25.0	23.9	38.0	24.0	24.5	34.0	10.4	6.6	3.0
149163e	20.6	16.9	28.0	?	23.4	23.4	8.0	5.1	none
169163f	16.9	14.3	21.0	14.0	20.4	20.4	6.0	4.3	none
149163g	12.2	10.9	14.0	?	14.0	14.0	2.8	1.3	none
149163h	7.2	6.1	9.5	8.2	8.7	8.7	2.7	0.9	none
149163i	20.4	16.0	30.0	22.5	19.5	24.1	14.1	7.0	?
149163j	24.2	19.4	36.0	28.0	26.0	34.6	12.2	9.3	?
USNM 712o									
149164a	34.8	26.0	45.0	31.0	28.0	37.4	9.6	7.3	6.0
149164b	26.8	?	38.0	33.0?	30.0	40.0	11.7	?	5.0
USNM 702un									
149157a	32.7	28.0	45.0	35.0?	27.0	50.4?	11.6	9.5	7.0
149157b	32.2	?	41.0	30.0?	27.0	46.0	11.1	?	12.5
149157c	33.0	28.7	40.0	35.0	32.0	46.9	13.3	10.7	10.0
USNM 702									
123908a	35.9	31.5	55.0	40.0	34.0	50.9	14.7	10.6	3.0?
123908b	29.9	25.0	41.0	31.5	30.0	51.5	10.4	5.0	3.0
123910	30.2	27.1	40.0	31.0	28.5	39.6	12.8	9.3	5.0
123909	25.5	21.2	38.0	28.0	26.0	43.2	11.6	7.7	?
149169a	36.2	31.7	51.0	39.0	36.0	54.4	15.8	11.9	8.0
149169b	31.9	28.0	58.0	37.3	27.5	50.3	13.2	9.2	5.0
149169c	33.2	27.3	46.0	32.8	32.0	41.6	12.0	9.3	4.0
149169d	33.1	23.6?	45.0	31.7	32.0	46.3	14.6	9.6	?
149169e	35.8	31.9	45.0	34.0	31.0	42.8	12.5	8.3	9.0
149169f	32.9	28.7	42.0	27.4	28.0	40.2	11.6	7.8	6.0
149169g	31.0	25.9	40.0	31.0	28.5	42.2	11.4	8.2	4.0
149169h	27.7	21.8	43.0	31.1	27.5	39.6	10.8	8.3	2.0
149169i	25.5	22.3	36.0	27.5?	32.0	34.4	10.4	7.9	none
149169j	25.3	21.7	32.5	19.3	31.6	31.6	7.3	5.2	none
149169k	22.0	19.0	27.0	17.8	26.5	26.5	8.2	4.6	none
149169l	19.9	18.2	22.0	19.3	24.6	24.6	4.9	2.2	none
149169m	17.1	15.0	20.0	15.0	18.7	18.7	4.7	3.8	none
149169n	13.7	12.6	15.0	12.0?	15.7	15.7	3.5	1.7	none
149169o	11.2	10.0	13.0	10.2	13.5	14.6	3.2	1.9	none
149169p	8.4	?	11.0	7.5	10.0	10.0	3.2	?	none
149169q	7.0	?	8.0	7.0	8.7	8.7	2.5	?	none
USNM 721u									
152663a	28.7	?	38.5	33.7	31.4	39.4	9.0	?	8.0
152663b	29.1	?	42.0	36.2	31.5	35.7	9.8	?	6.0
152663c	34.0	31.4	44.5	35.6	28.0	39.0	10.8	6.9	11.5
152663d	21.9	?	28.0?	21.9	27.7	28.4	7.3	?	none
152663e	15.5	?	20.0	15.8	18.3	18.3	4.4	?	none
152663f	8.4	?	10.5	9.8	11.2	11.2	2.8	?	none
152663g	5.9	?	6.5	6.3	7.8	7.8	1.9	?	none

by concentric wrinkles forming conspicuous reticulation with costellae; reticulation not extended to anterior slope. Ornament spines rare, confined to posterior and median portions of visceral disc area; rhizoid spines stout, long, generally confined to ears and posterior margin except in young, there also occupying umbonal slope. Attachment by cementation of beak, and anchoring by rhizoid spines. Brachial valve without spines.

Pedicle valve unevenly convex in lateral profile, posterior two-thirds moderately to fairly strongly convex, anterior third geniculated ventrad at angles ranging up to right angle; anterior profile bilobed, each lobe moderately convex and separated by narrow sulcus, overall profile broadly domed. Beak small, umbo narrowly swollen; median region moderately to strongly swollen, forming two mounds on each side of sulcus; umbonal slopes moderately steep but lateral slopes very steep. Sulcus originating about 5 mm anterior to beak, narrow and shallow at place of origin but deepening and widening anteriorly to divide valve into two rounded lobes. Frill broad, extending abruptly in ventral direction, generally somewhat flattened near ears but steepening anteriorly to bound deep V-shaped trough around valve; some specimens with margin of frill directed dorsad to form gutter, deep and wide when viewed from dorsal side. Interarea usually short and nearly flat.

Brachial valve generally moderately but unevenly concave, deepest concavity opposite swollen flanks of pedicle valve; umbonal region a deep pit depressed with low, carinate fold originating just anterior, heightening anteriorly to form carinate crest at front. Ears flattened or sloping gently toward frill, demarcated by low, oblique ridge. Geniculation occurring at about anterior third. Frill bending abruptly ventrad to fit over that of pedicle valve.

Pedicle valve interior divided into two chambers by carinate ridge produced by deep exterior sulcus; diductor scars broadly flabellate but adductor field narrow, perched on crest of median ridge.

Brachial valve interior with short, stout, short-shafted cardinal process. Lateral ridges concave, strong and thick in adults, joining cardinal process. Adductor field moderately thickened, with smooth anterior scars but dendritic posterior impressions. Brevisseptum extending anterior to midvalve, high, slender, and delicate, anterior slope marked by numerous fine endospines.

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation, Cathedral Mountain Formation (and Wedin Member), Cibolo Formation (spicule zone of Udden), Road Canyon Formation.

LOCALITIES.—Bone Spring: AMNH 658. Wedin: USNM 700-1, 700x, 714w, 717e, 727p. Cathedral Mountain: AMNH 500, 500F, 500H, 500L, 500N, 500x; USNM 702, 702b, 702ent, 702-inst., 702-low, 702un, 703b, 703bs, 707q, 708, 709, 709o, 710d, 712o, 713t, 721u, 723n, 723u, 723v, 723y, 724i, 724m, 724n, 724r, 724s, 724t, 726x, 727q, 727x, 730q, 730u, 731b, 731n, 735b, 736t, 737v, 741s. Cibolo: USNM 725v, 738f, 738o. Road Canyon: AMNH 501.

DIAGNOSIS.—Deeply sulcate *Institella* with wide frill, moderately strong costellae and crowded concentric wrinkles.

TYPES.—Holotype: YPM 10706. Figured paratypes: YPM 10712, 10715. Figured hypotypes: USNM 123908; 123912a-c; 124137c-f; 149147a-d; 149153a, c-e, g, h; 149157a, b; 149163a; 152663c; 153917; 153970a, b; 154195a-j; 154196a-e, g, i-u; 154197; 154198; 154584. Measured hypotypes: USNM 123908a, b; 123909; 123910; 149157a-c; 149163a-j; 149164a, b; 149169a-q; 152663a-g.

DISCUSSION.—The deeply sulcate pedicle valve and prominent frill of this species separate it from most productids found in North American Permian rocks. *I. salomonensis* (Gemmellaro) from the Sosio Limestone of Sicily is of about the same size but differs markedly in details of the ornament and also in having a much broader sulcus and somewhat more elaborate frill. *I. subsinuata* (Licharew) from the North Caucasus is large, with more regularly reticulate ornamentation.

GROWTH.—Young *Institella* attaches directly by its umbonal region to other shells or hard objects. The smallest specimen seen is a shallow cup attached by most of its ventral surface. As growth continues anchor spines are soon sent out from the anterior and lateral parts of the growing cup. In some instances these form rings if the object to which the specimen is attached is small and round. Usually the cicatrix of attachment of young shells that have broken from their moorings is surrounded by short anchor spines. Some of these come from the anterior slope of the umbo of the tiny shell. These are the only spines noted from this portion of the shell and adults do not send out anchor spines from this part. Evidently these umbonal



spines were needed to anchor the small shell as its hinge grew.

As the hinge extends laterally, spines appear near its edge and on the ears. These grow until they strike a solid object and then cement to it. Anchor spines on the ears attain a length of several inches.

The smallest institellas in the collection are strongly convex and the ornament consists mostly of concentric wrinkles. The brachial valve is deeply concave and fits closely within the pedicle valve. With continued growth the shell becomes less convex, so that medium-sized specimens that have not yet geniculated or developed a frill are shallow and almost planoconvex.

Geniculation takes place before the development of the frill, but after geniculation the shell becomes increasingly convex until the adult form is reached. At lengths of 20 to 25 mm the frill starts to form. This appears generally at the anterolateral extremities and grow around both sides. Growth on the sides seems to have been more rapid than that at the distal end of the sulcus.

STRATIGRAPHY.—R.E. King (1931:71) records this species as "a very abundant and widespread Leonard fossil." In our experience the species is characteristic of the Cathedral Mountain Formation. It is widespread in the Glass Mountains, but appears to be abundant only in a few places, such as at Split Tank. At USNM 714w, which occurs on the top of a small knob in the western part of the Glass Mountains, the species was abundant in small patches of rock. The species is evidently locally abundant in bioherms where it is gregarious in its habit. At some other localities it seems to be in the form of dead shells transported to the site where found.

The earliest occurrence for this species is in the Wedin Member (Second Limestone Member of the Leonard of P. B. King), where it occurs with *Agelesia triagonalis* (King), which seems to mark one general level. The association in the Wedin Member suggests the same zone as seen at USNM 703bs and the lower levels just above the Hess Formation at Split Tank. This also includes the association in the small fault block at USNM 708, which has essentially the same fauna as the Wedin Member, and the lower beds at Split Tank (USNM 702un). At USNM 702un *I. leonardensis* is abundant with *Torynechus* just above the Hess Forma-

tion and conglomerate. The lower 40 feet of the Cathedral Mountain Formation here abounds in *Institella*, which also appears at another level about 75 feet above the lower one. The specimens at this higher level are mostly worn and detached, whereas those from the lower beds appear to be from bioherms.

R.E. King (1931:71) records the species from a limestone in the middle of the Word Formation at his locality 48 but we have not seen it in rocks of this age.

### *Institella salomonensis* (Gemmellaro)

PLATE 246: FIGURES 1-4

*Productus salomonensis* Gemmellaro 1892:26.

Pictures of this species are introduced for comparison with those of *I. leonardensis*. The Sosio shells are about the same size as large specimens from the Glass Mountains but are more compressed and have a less carinate frill.

STRATIGRAPHIC OCCURRENCE.—Sosio Limestone Formation.

LOCALITY.—USNM 755.

TYPES.—Figured specimens: USNM 149167a, b.

### *Institella* species undetermined

PLATE 246: FIGURE 5

A second species of *Institella* from the Sosio Limestone is illustrated for comparison with *I. leonardensis*. This is a small species, more strongly ornamented and more convex and with a strong sulcus.

STRATIGRAPHIC OCCURRENCE.—Sosio Limestone Formation.

LOCALITY.—USNM 755.

TYPE.—Figured specimen: USNM 149166.

### *Glyptosteges*, new genus

[Greek *glyptos* (carved) + *steges* (chamber)]

Small to medium, usually transversely subquadrate in outline, hinge commonly widest part. Ears obtuse to angular; strongly concavo-convex; inter-area variable, usually small and narrow. Pedicle valve medially sulcate. Umbonal attachment scar usually small, not impressed in some specimens. Spines rhizoid and ornamental, former in row

along posterior margin and ears, latter scattered over venter and over lateral and anterior slopes. Surface of both valves strongly sculptured, visceral disc reticulated, sides and trail marked by strong rounded costae; ears and lateral slopes marked by regular, closely spaced, wavy, elevated lines producing reticulation of visceral disc.

Pedicle valve interior with ear region forming flattened shelf with baffle; adductor field forming two elevated tracks surrounded by flabellate diductor scars.

Brachial valve with small sessile cardinal process, bilobed on ventral side but trilobed on posterior side, median lobe moderately large; lophidium small; lateral ridges thick, forming elongate mound near cardinal process and extending laterally inside lateral margins as low ridge. Adductor field small, scars thickened and forming low mound. Brachial ridges moderately large, slightly oblique. Brevisep-tum well developed.

TYPE-SPECIES.—*Glyptosteges intricatus*, new species.

DIAGNOSIS.—Strongly sculptured and anteriorly costate Aulostegidae.

COMPARISON.—*Costispinifera* Muir-Wood and Cooper and *Oncosarina* Cooper and Grant have similar types of costae and concentric ornament. Inasmuch as neither of these are attached as adults, they do not belong to the Aulostegidae and are not difficult to separate from *Glyptosteges*. Neither has an interarea and the brachial interior of *Costispinifera* has thick endospines and a different cardinal process; *Oncosarina* does not have an interarea, always has a convex visceral region, but has only a slight median sulcus in the pedicle valve and a small marginiferid cardinal process in the brachial valve.

Three genera of the Aulostegidae are ornamented somewhat like *Glyptosteges* and all are anteriorly costate. These are *Strophalosiina* Licharew, *Chonosteges* Muir-Wood and Cooper, and *Urushtenia* Licharew. Although details of the ornament of the first two are like those of *Glyptosteges*, these two genera are unlike *Glyptosteges*. *Strophalosiina* has a much more highly developed interarea and has a well-formed elytridium, a structure not developed in *Glyptosteges*, the delthyrium of which is closed by the cardinal process and lophidium. The same features characterize *Chonosteges* and serve to distinguish it from *Glyptosteges*,

but *Chonosteges* has, in addition to the cardinal structures, a peculiar spine arrangement which has no counterpart in any other American genus.

*Urushtenia* strongly suggests *Glyptosteges* but many differences between the two can be seen at a glance. The ornament of *Urushtenia* is much more regular than that of the American shell, the concentric ornament being laid down in even curves, in contrast to that of *Glyptosteges*, which is wavy and irregular. *Urushtenia* has only a slight development of a sulcus on the pedicle valve. It also has a spinose anterior margin that has not been seen in any specimens of the American genus. Irregularity in the development of a scar of attachment and development of an interarea are features that the Russian and American shells share in common.

DISCUSSION.—Generally speaking this is a rare genus. It is commonest in the Skinner Ranch Formation, especially in the Dugout Mountain Member, but is rarer in the higher parts of the formation. It is fairly frequent at the top of the Sullivan Peak Member in the western part of the mountains. It occurs rarely in the basal beds of the Cathedral Mountain Formation. At USNM 723k it is clearly *G. intricatus*, new species; at USNM 721u, however, the specimens are quite unlike those from the Sullivan Peak Member, and only 12 specimens were obtained from more than one ton of rock.

### *Glyptosteges angustus* (R. E. King)

PLATE 208: FIGURES 9–12; PLATE 250: FIGURES 1–28; PLATE 253: FIGURE 10

*Marginifera reticulata* R. E. King (part), 1931:89, pl. 22: figs. 5a, b.

*Marginifera reticulata angusta* R. E. King (part), 1931:89, pl. 22: figs. 11–14 [not 15].

Shell small, subquadrate in outline, hinge generally forming widest part; ears obtuse to extended, narrowly rounded when extended; sides gently rounded; anterior margin broadly rounded.

Pedicle valve unequally convex in lateral profile, posterior flattened, median region narrowly rounded, anterior or trail gently swollen, anterior profile broad, moderately convex dome with steep sides. Beak small; umbonal region gently inflated with short moderately steep umbonal slopes extending to ears; median region swollen; anterior slope or trail long and steep. Ears deflected, some-

what flattened. Lateral slopes and base of ears marked by strong concentric lines; visceral disc reticulated; anterior and lateral slopes marked by 17 to 24 costae, three or four occupying sulcus; sulcus shallow, moderately wide, not conspicuous, originating at anterior of visceral disc and extending to anterior margin. Lateral slopes precipitous.

Brachial valve moderately concave, deepest part divided medially by low fold originating just posterior to midvalve; anterior slopes steeply descending medially; ears flattened; umbonal region moderately depressed. Sculpture as on pedicle valve.

Pedicle valve interior with open delthyrium and low, elongated adductor callosity. Diductor scars elongate, flabellate.

Brachial valve interior with moderately large cardinal process bilobed in ventral view but with trilobed myophore in posterior view. Lateral ridges posteriorly thickened, thinning laterally to form low subperipheral rim; adductor scars forming subelliptical to suboval elevated patch; brevisseptum highest anteriorly, not extending posteriorly beyond middle of adductor field. Brachial ridges widely oblique. Endospines short and thick, in two rows across anterior of visceral disc.

MEASUREMENTS (in mm).—Thickness of specimen 152667d, from locality USNM 707d, is 2.2 and of 152670a, from 722-1, is 3.6; of others, unmeasurable.

	length	brach- ial valve length	sur- face length	mid- width	hinge width	height
King loc. 4						
YPM 11807a	15.3	?	25.0	18.5	14.7+	8.0
(lectotype)						
USNM 707d						
152667a	13.5	12.4?	21.0?	17.2	13.9?	7.4
152667b	12.0	10.5?	16.0	16.5	16.9	7.2
152667c	13.7	11.5	21.0?	21.2	21.6*	7.8
152667d	11.6	10.2	18.0	14.8	11.9	6.3
152667e	14.6	13.1?	24.0	18.8	17.3	9.3
152667f	14.5	12.3	27.0	19.0	18.3	8.9
152667g	15.8	12.4	27.0	18.4	22.9	9.0
USNM 722-1						
152670a	17.0	13.9	30.5	21.8	25.3	10.8
152670b	16.7	?	28.5	21.4	17.7	11.9
152670c	16.5	?	28.5	21.9	21.2	10.2
152670d	13.8	?	24.0	17.8	17.8	8.5
152670e	14.6	?	25.5	19.7	17.8	9.4
152670f	12.0	?	20.0	16.0	14.8	7.3

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch

Formation (Decie Ranch, Poplar Tank, and Sullivan Peak members), Hess Formation.

LOCALITIES.—Decie Ranch: USNM 708q. Poplar Tank: USNM 708e. Sullivan Peak: USNM 707b, 707d, 709-1, 722h, 722-1, 727a, 729p, 733j. Skinner Ranch: USNM 723q, 724-1. Skinner Ranch (top): USNM 722m. Hess: USNM 729u.

DIAGNOSIS.—Strongly convex and strongly costate *Glyptosteges*.

TYPES.—Lectotype (herein designated): YPM 11807a. Figured paratypes: YPM 11806a, b; T10290 (part). Figured hypotypes: USNM 152667e, g, h; 154192; 154193a-f; 154194a. Measured hypotypes: USNM 152667a-g, 152670a-f. Figured specimen: YPM 11729.

COMPARISON.—This species is less strongly sculptured and more convex in the visceral disc region than *G. intricatus*, new species. It is larger than *G. insculptus*, new species, but the costae on the trail are less prominent and somewhat more crowded, and the umbonal and visceral regions are much more swollen.

DISCUSSION.—King's types are all listed as cotypes, and two lots are at Yale. Lot YPM 11807 consists of two specimens, one of which, narrow and deeply sulcate, may be designated as 11807b, and because of its deep sulcation is excluded from the species. The other specimen has a shallow sulcus and a strongly costate trail; the best preserved of the Yale specimens, it is here selected as lectotype YPM 11807a (R. E. King, 1931, pl. 22: fig. 11).

Lot YPM 11806 consists of two specimens, neither well preserved. The two seem conspecific with the lectotype but are smaller, with more subdued ornament due to their more youthful age and somewhat decorticated preservation.

At Austin is preserved another lot of cotypes (T10290) consisting of two specimens, one of them, the larger, seems conspecific with the lectotype, but the other is very narrow and is probably a different species. The lectotype is from the Leonard (= Skinner Ranch Formation) 0.6 mile N of hill 5021, Altuda quadrangle; the paratypes are from loc. 26S in the Leonard (= Sullivan Peak)?

This is not a rare species, especially in the upper part of the Skinner Ranch Formation and the Sullivan Peak Member (which is essentially equivalent to the top of the Skinner Ranch). Specimens are often embedded in the skin of chert that is common on the upper surface of some layers of the

Sullivan Peak Member and Skinner Ranch Formation. These specimens are often so buried as to obscure many details, and interiors are few. Furthermore, it is difficult to obtain good blocks from this part of the column that yield clean shells. The result is that we have the species represented at many localities but only USNM 722-1 yielded many good specimens.

*Glyptosteges insculptus*, new species

PLATE 249: FIGURES 1-24

Small to medium, rectangular, transverse, hinge widest part; ears deflected, varying from obtuse to extended and narrowly rounded. Sides obliquely rounded; anterior margin broadly rounded to gently emarginate. Posterior half reticulated, anterior half costate, costae narrowly rounded with narrow interspaces. Costae numbering about 16, with 1 or 2 in sulcus. Rhizoid spines concentrated on posterior margins, ears, and lateral slopes; ornament spines few, occurring on visceral disc, few scattered on trail.

Pedicle valve strongly convex in lateral profile, maximum and narrow curvature slightly posterior to midvalve, posterior somewhat flattened, trail slightly convex. Anterior profile a broad dome on crest, or medially concave, sides steep. Sulcus originating slightly posterior to midvalve, variable but seldom strong, usually narrow, shallow, occupied by one or two costae, or with none. Median costae often pinched out by anteromedian convergence of costae bounding sulcus. Flanks rounded and swollen; ears depressed and deflected. Scar of attachment varying from invisible to broad and flat.

Brachial valve moderately concave, deepest in anterolateral regions; anterior slope steep, lateral slopes less so. Median fold poorly developed, low and narrow, originating near midvalve. Ears flattened to slightly concave.

Pedicle valve interior with small, inconspicuous interarea; adductor track narrow, not strongly thickened. Ears baffles moderately developed.

Brachial valve with bilobed cardinal process of moderate size. Other details not known.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
AMNH 591							
152671a	12.0	10.6	21.5	19.6	16.0	7.3	?
152671b	13.0	10.3	21.0	14.5	15.5	7.0	3.9
152671c	11.6	9.5	19.0	12.5	14.0	6.1	3.0
(holotype)							
152671d	12.7	?	21.0	21.6*	19.8	?	?
152671e	15.0	?	23.0	?	19.7	7.9	?
152671f	11.7	9.8	18.0	16.9	15.2	6.2	3.3
152671g	12.8	?	20.0?	16.5	15.7	7.6	?

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation (40 feet above base in lowest reef lenses).

LOCALITIES.—AMNH 492, 591.

DIAGNOSIS.—*Glyptosteges* of medium size, usually with prominent, narrowly rounded costae on the trail.

TYPES.—Holotype: USNM 152671c. Figured paratypes: USNM 152671b, f; 154190a-c. Measured paratypes: USNM 152671a, b, d-g. Unfigured paratypes: USNM 152671a, d, e, g.

COMPARISON.—This species is most like *G. angustus* (R. E. King) but it is less strongly swollen in the umbonal and visceral disc regions, is smaller,

and usually has a more strongly entrenched sulcus. The costae on the sulcus are usually narrower and more distant, but variable.

DISCUSSION.—This is a highly variable species but we have too few specimens to make a good statement on the degree of variability. Costae on the trail vary in number, size, and roundness but they tend to be well separated from one another. One specimen of this species was found, in its position of growth, attached to a smooth brachiopod, probably a *Composita*. It is attached in the same manner as several other ornate aulostegids such as *Spyridiophora* Cooper and Stehli and *Institella* Cooper.



*Glyptosteges intricatus*, new species

PLATE 249: FIGURES 25–62; PLATE 250: FIGURES 29–31

*Marginifera reticulata* R. E. King (part), 1931:89, pl. 22: figs. 5a, b.

Fairly large for genus, wider than long, rectangular outline, hinge slightly wider than midwidth; sides gently rounded; anterior emarginate. Trail marked by 18 to 20 strong, rounded costae, 2 or 3 in sulcus. Visceral disc and ears marked by irregular, wavy concentric lines causing strong cancellation of radii on visceral disc. Rhizoid spines confined to row at base of umbonal slope, scattered spines on ears and along posterior margin. Ornament spines few, widely scattered.

Pedicle valve moderately but unevenly convex in lateral profile, posterior somewhat flattened, median region narrowly convex, trail forming moderately steep slope. Anterior profile broadly convex but deeply indented medially, lateral slopes steep. Ears flattened, sharply deflected and obtuse. Beak small; umbonal region narrowly swollen, umbonal slopes steep. Sulcus originating on anterior side of umbonal region posterior to midvalve, narrow, deepening anteriorly to margin, there forming indentation. Costae on sides of sulcus directed anteromedially. Flanks bounding sulcus, narrowly rounded and strongly swollen. Interarea well developed.

Brachial valve with strong concentric wavy ornament, moderately concave, deepest in anterolateral regions, median fold low, originating at about midvalve; ears flattened.

Pedicle valve interior with strong ear baffles above row of holes corresponding to strong row of spines at base of umbonal slope. Adductor track moderately thickened.

Brachial valve with poorly developed lateral ridges; adductor field small, moderately thickened. Endospines numerous, short, and stout.

MEASUREMENTS (in mm).—Thickness of holotype 6.0; of others, unmeasurable.

	brach- ial valve length	sur- face length	hinge width	mid- width	height length
USNM 732e					
154191b	17.9	15.3	26.0	15.9	20.3
(holotype)					
152672a	16.0	13.7	22.0	19.0	20.4
152672b	?	10.8	?	10.1	15.1
USNM 715o					
152673	14.0	?	21.0	19.6*	18.4

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch, Dugout Mountain, and Sullivan Peak members), Cathedral Mountain Formation.

LOCALITIES.—Decie Ranch: USNM 707g, 720f. Dugout Mountain: USNM 700r, 707b, 713d, 715f, 715o, 722h, 722–l, 727a. Sullivan Peak: King 228, USNM 700o, 700p, 700s, 707d, 732d, 732e, 733–l. Skinner Ranch: USNM 705r, 705n, 705o, 710r, 722m, 723h, 723–l, 723o, 724–l, 727m, 727n, 729m, 731o. Cathedral Mountain: USNM 713v, 723k, 731q.

DIAGNOSIS.—*Glyptosteges* with flattened and strongly sculptured umbonal and visceral regions.

TYPES.—Holotype: USNM 154191b. Figured paratypes: USNM 152669; 152672a; 154191a, c–g. Unfigured paratypes: USNM 152673; USNM 152672b; 154191b, e. Measured paratypes: USNM 152672a, b; 152673.

COMPARISON.—The flattened and highly sculptured visceral disc of this species distinguishes it from the other species described here.

DISCUSSION.—This species is less common than *G. angustus* (R. E. King) in the Glass Mountains. It has not been found in well-preserved condition except at USNM 723k and 732e because it is frequently embedded in chert or siliceous beds. Present indications point to its range throughout the Skinner Ranch Formation and spilling over into the base of the Cathedral Mountain Formation, but it is rare in the Decie Ranch Member, and we have not seen it in the Poplar Tank Member.

*Glyptosteges sulcatus*, new species

PLATE 250: FIGURES 32–46; PLATE 468: FIGURES 11–22

Pedicle valve wider than long, small ears extended slightly beyond midline. Profile moderately convex but with rounded venter; slightly flattened visceral disc region strongly reticulated, but not so much as in *G. intricatus*, new species. Sulcus originating on visceral disc, narrow but deep, occupied by two costae at margin. Costae on trail distant, high, narrowly rounded, numbering 7 per side, including sulcus.

Brachial valve moderately concave, with more deeply concave umbonal region. Visceral disc irregularly sculptured. Genuiculation occurs at two-thirds length. Cardinal process low, sessile, bilobed in ventral aspect. One specimen with anterior adventitious projections.

**MEASUREMENTS** (in mm).—From locality 721u, specimen USNM 152674a (holotype): length 13.9, brachial valve length 12.3, surface length 22.0, mid-width 16.9, hinge width 18.8\*, height 7.7, thickness 3.8.

**STRATIGRAPHIC OCCURRENCE**.—Cathedral Mountain Formation (lower).

**LOCALITIES**.—USNM 721u, 741k.

**DIAGNOSIS**.—Medium-sized *Glyptosteges* with moderately swollen visceral region, short, deep sulcus and distant costae on the trail.

**TYPES**.—Holotype: USNM 152674a. Figured paratypes: USNM 152674b–c, e–g; 153918a, b.

**COMPARISON**.—This species is less anteriorly costate than *G. angustus* (R. E. King) but is smaller, and the few specimens we have suggest that it is also narrower. It is a more convex form than *G. intricatus*, new species, and, like that species, is a survivor into the base of the Cathedral Mountain Formation.

### *Craspedona*, new genus

[Greek *kraspedon* (border)]

Medium-sized Productacea having a subrectangular outline; profile concavo-convex; hinge forming the widest part; ears broad and prominent; interarea short and inconspicuous; delthyrium open; umbonal cicatrix minute; attachment by umbonal cementation, spine rings, and stout rhizoid spines along posterior margin and on ears. Surface marked by subdued costellae; no ornament spines; both valves surrounded by ventrally deflected frill, outer groove defined by dorsal fold; deeply sulcate to subsiphonate medially.

Pedicle valve with widely flabellate diductor scars, but adductor field not thickened; myophragm threadlike, inconspicuous. Visceral region surrounded by elevated, carinate rim extending from delthyrial angles around each side and anterior, somewhat elevated medially to form subangular projection. Visceral marginal elevation defining deep groove, or gutter, bounded on exterior by dorsally directed fold of frill.

Brachial valve with elongate, slightly thickened adductor field divided by long, slender median septum; cardinal process small, sessile, consisting of narrow trilobed myophore surmounting bilobed shaft, each lobe of shaft tapering anteriorly to point; shaft supported by and partially buried in

adventitious shell. Posterodorsal side of cardinal process covered by arched zygidium with elongate, narrow lophidium outside it. Visceral area defined by deep, angular groove bounded by ventrally deflected frill. Endospines small, covering anterior slope. Brachial ridges well defined.

**TYPE-SPECIES**.—*Craspedona newelli*, new species.

**DIAGNOSIS**.—Frilled Aulostegidae with sessile cardinal process protected by a zygidium.

**COMPARISON**.—The attached habit of this genus separates it from other genera having a zygidium, such as *Paucispinifera* Muir-Wood and Cooper. Presence of the ventrally directed frill with its reverse deflection is like *Institella*, and the entire aspect of this brachiopod is like that genus. *Craspedona*, however, differs from *Institella* in interior and exterior details, even though their general appearance and frills are similar. Exterior differences consist of lack of reticulation of the visceral disc region and a less prominent development of the palintrope and interarea. The chief interior differences are in the brachial valve. The cardinal process of *Craspedona* is sessile, with a posterior zygidium, quite unlike that of *Institella*.

**DISCUSSION**.—The presence of a small umbonal cicatrix and stout rhizoid spines along the posterior margin and on the ears of members of this genus indicates that their living habits were like those of *Institella*. They were undoubtedly anchored to the substrate through most of their lives, in a vertical or nearly vertical position. If wrenched from their moorings they would have been capable of existence free on the sea floor, by virtue of the peculiar frill surrounding the visceral area. This structure originates as a ventrally directed wall surrounding the visceral area of both valves. When this reaches the approximate level of the exterior of the pedicle valve, it deflects horizontally and then dorsally to produce a deep groove surrounding the valves, deepest at the anterior margin but widening and becoming shallow at the ears. Anteriorly at midvalve the frills of both valves are narrowly puckered to form a partial or nearly complete tube or siphon. It is presumed that the frill, gutter, and siphon are devices to facilitate feeding.

A feature of the pedicle valve requiring remark is the abbreviation of the palintrope and, consequently, of the interarea. In some specimens, in fact, it may be questioned whether any palintrope exists. This is unusual for a wide-hinged and at-

tached brachiopod, most of which have the hinge region strengthened by a palintrope. The development of the zygidium is probably a consequence of the shortening and disappearance of the palintrope.

The most unusual feature of *Craspedona* is the cardinal process, which resembles that of the Richthofeniidae to some extent. The cardinal process has a moderately long, narrow shaft, grooved medially, with each lobe tapering to a point anteriorly. This suggests the peculiar points growing anteriorly from the cardinal process of *Echinosteges*, *Edriosteges*, and some other members of the Aulostegidae. The myophore has a narrow median lobe surrounded by two yet narrower lobes which extend slightly beyond the level of the median lobe and define two deep concentrically striated grooves. The zygidium arches over the distal end of the myophore and may overhang the myophore for fully half its length. When viewed from the posterior, the zygidium appears to occupy a median position relative to the myophore and the outside of the valve. On the outside of the zygidium and at right angles to it, a short carinate lophidium is prolonged dorsally to form a small triangular lip protruding from the posterior margin. Articulated specimens indicate that the zygidium and lophidium fit inside the pedicle valve umbonal chamber, but the small triangular lip protrudes. As mentioned above, this may be a device to close the wide delthyrium.

### *Craspedona newelli*, new species

PLATE 254: FIGURES 1-27

*Productus* species d Girty, 1909:273, pl. 29: figs. 4, a, b [not pl. 20: figs. 19-21a].

Subrectangular in outline, attaining maximum width about 25 mm along hinge; sides gently curved; anterior siphonate. Surface costellate, cos-region broadly flattened, demarcated from ears and tellae subdued and flatly rounded, about 5 in 5 mm on anterior slope. Rhizoid spines generally short but stout, occupying ears and posterior margin. Ears prominent, narrowly folded anteriorly and merging into lateral gutter and frill.

Pedicle valve irregularly convex in lateral profile, posterior two-thirds nearly flat but anterior third narrowly geniculated; anterior profile broadly flattened; beak small and inconspicuous, not in-

curved, not protruding. Umbonal and median lateral frill by anteriorly deepening groove and lack of ornament on ears; geniculated region broadly to somewhat narrowly folded at about 10 to 12 mm anterior to beak; anterior slope forming most distinctly costellate part of shell, steep and descending into narrow groove defined by frill. Anterior slope with prominent median sulcus terminating in subcarinate tongue. Anterior frill nearly vertically or steeply inclined away from visceral region, narrowly folded dorsad deflection at about level of exterior surface of pedicle valve. Dorsad deflection defining U-shaped trough. Median point of frill opposite sulcus marked by narrow and deep groove forming semisiphon. Posterior third nearly smooth, as costellae become indistinct posteriorly.

Brachial valve exterior moderately concave in lateral profile, with greatest concavity in anteromedian region bounding frill. Umbonal region concave, concavity forming narrow band but disappearing near midvalve, where poorly defined median elevation appears. Lateral regions concave. Visceral region bounded by strongly elevated and carinate ridge with outer side forming ventrally deflected part of frill; ears flattened but marked by short oblique groove leading into gutter of frill. Exterior of frill and surface of visceral region indistinctly costellate.

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member), Bell Canyon Formation (Hegler, Pinery, and Rader members), Delaware Mountain Formation.

LOCALITIES.—Getaway: AMNH 512. Hegler: AMNH 635; USNM 731, 732a, 740c, 740d. Pinery: AMNH 398, 537; USNM 725h, 733, 736a, 748. Rader: AMNH 403; USNM 725f, 725g, 740a, 740g, 740i, 740j. Delaware Mountain(?): USGS 2969.

TYPES.—Holotype: USNM 154172a. Figured paratypes: USNM 149442, 149443c, 152664f, 154171a-g, 154172b-e, 154173. Measured paratypes: USNM 149442; 149443a, b, d; 149444b, 152664a-f. Unfigured paratypes: USNM 149443a, b, d; 152664a-e.

COMPARISON.—No other unequivocal species of this genus is known to which *C. newelli* may be compared. It is much wider than *C.?* *limbata* (Girty).

DISCUSSION.—This is an exceedingly rare species and is seldom well preserved, the median portion normally is poorly silicified or broken. As would be

## MEASUREMENTS (in mm).—

	length	brachial valve length	hinge width	midwidth	height	thickness	frill length
USNM 731							
154172a	16.5	13.9	19.0+	19.1	7.0	3.1	5.0
(holotype)							
149443a	19.0	18.5	31.6	24.0	8.0+	4.4	5.7
149443b	18.0	16.9	?	22.6	6.6	?	6.0
149443d	12.7	?	26.0	24.0	6.4	2.4	8.0
USNM 733							
149444b	20.5	?	26.5	24.0	6.7	?	7.0
AMNH 635							
149442	16.0	?	24.0	24.0	7.5	?	4.0
USNM 725f							
152664a	16.9	?	22.6	23.3+	7.9	?	5.0
152664b	18.3	?	20.0	21.3	7.8	?	6.0
152664c	15.0	?	19.7	23.0	6.7	?	5.0
152664d	13.0	?	21.0	18.0+	7.4	?	2.5
152664e	13.4	?	16.7?	17.0	6.4	?	1.5
152664f	?	18.7	16.5	20.5	?	?	10.0

expected, it is highly variable, especially in development of the frill, which is often short but in some specimens is extremely long. The semi-tubular anteromedian part also is variable, some specimens being narrowly angular, others broad and rounded. The collection is too small to detect any consistent differences among specimens from the various levels of the Bell Canyon Formation.

*Craspedona? limbata* (Girty)

*Productus limbatus* Girty, 1909:272, pl. 20: figs. 17, 18.

This species is based on two poorly preserved specimens, one a pedicle valve and the other a brachial valve with part of the pedicle valve in place. The latter specimen gives opportunity to study the narrow visceral region. The valves taper posteriorly, giving the shell a triangular form. One specimen, the lectotype (Girty, 1909, pl. 20: fig. 17) preserves part of a flattened ear with the trace of one large spine. Neither specimen shows any clear evidence of reversal of growth direction along the anterior and lateral margins to produce a frill. The specimen suggests a *Craspedona* which has not yet formed its frill or one from which it has been broken away. Subdued costae appear along the anterior margin of both valves.

MEASUREMENTS (in mm).—From locality USGS

2930 (green), specimen USNM 118542a (lectotype): length 16.6, width 16.4, thickness 3.5.

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Pinery Member).

LOCALITY.—USGS 2930 (green).

DIAGNOSIS.—Elongate, subtriangular *Craspedona?*

TYPES.—Lectotype (herein designated): USNM 118542a. Figured paratype: USNM 118542b.

Family SPYRIDIOPHORIDAE Muir-Wood  
and Cooper, 1960

Aberrant Aulostegidae having lost interarea; brachial valve with elaborate adductor platforms forming spyridium; cardinal process bilobed, alveolus developed.

Genus in West Texas: *Spyridiophora* Cooper and Stehli, 1955.

This genus in the Glass Mountains ranges from the Neal Ranch Formation through the Skinner Ranch Formation. It is generally rare in the Neal Ranch and Lenox Hills formations. It is rare in the Decie Ranch Member of the Skinner Ranch Formation, but becomes increasingly abundant to the top of the Skinner Ranch where it is common. It is the chief guide fossil to the Upper Skinner Ranch. In the Sierra Diablo it occurs in the Lower Bone Spring equivalent to the Skinner Ranch Formation. It has been found as a great rarity in the base of the Cathedral Mountain Formation.



### Genus *Spyridiophora* Cooper and Stehli, 1955

*Spyridiophora* Cooper and Stehli, 1955:471.—Muir-Wood and Cooper, 1960:144.—Williams et al., 1965:H460.

Small to medium, transversely rectangular, hinge wider than midwidth; ears prominent, separated from flanks by prominent spine-bearing ridge; anterior margin broadly rounded. Visceral disc short; area of geniculation narrowly rounded; trail long. Visceral disc strongly reticulate; trail strongly costate. Visceral disc with short, slender, oblique ornament spines; trail with erect stout spines springing from costae; lateral ridge bearing strong, erect spines. Shell attached by rhizoid spines on umbo and posterior margin. Sulcus of pedicle valve deep; brachial fold carinate.

Pedicle valve with short interarea. Interior with strong lateral ridges across ears; adductor field thickened; diductor scars flabellate.

Brachial valve interior with strong ridges extending from cardinal process, curving inside ears, and extending along inside of anterior margin, dying out at sulcus. Adductor platform elevated and supported by strong plates; plates united or separate, when united forming basket-like structure—the spyridium; brachial ridges narrow. Cardinal process bilobed, attached to spyridium. Median septum long, slender, and highest anteriorly.

TYPE-SPECIES.—*Spyridiophora distincta* Cooper and Stehli (1955:473, pl. 54: figs. 1–17).

DIAGNOSIS.—Reticulate, costate, and strongly geniculate Aulostegidae having a spyridium in the brachial valve.

DISCUSSION.—Several anatomical features of this genus, such as the exterior form and the peculiar internal spyridium, are worthy of note. The exterior expression of this genus is that of a small and wide dictyoclostid. The reticulation of the visceral disc areas is very strong and sharply defined. The radial costae are strong, but what makes the emphasis in the reticulation is the fact that the concentric wrinkles are unusually regular. Where the radial and concentric elements intersect, a small node is created, but between these elements is a deep pit that emphasizes the reticulation.

Geniculation is very prominent and is so strong on some specimens that the trail and visceral disc surfaces are approximately parallel. The trail is moderately to very long, in one species twice the surface length of the visceral disc. Strong costae

only mark the trail, those bordering the sulcus may lie oblique to the others and “toe-in” to the sulcus. In all species the sulcus is deep and narrow, generally dividing the shell into two lobes. A dorsal fold is developed, more or less strongly carinate and prominent depending on the strength of the sulcus.

Perhaps the most surprising feature of *Spyridiophora* is the fact that it is an attached form. Whether or not it was attached throughout life is not known surely, but it was securely fastened by rhizoid spines and umbonal cementation, in some until adulthood. Rhizoid spines appear on the umbo and along the hinge margin but these are only part of the anchorage of the shell. A row of rhizoid spines along the ridge separates the ear from the pedicle valve flank. Ornament spines on the visceral disc arising from the costae are generally short and slender. Other erect spines on the trail arise from the costae.

The ears of this genus are also unusual in their development and may have been the channels through which water currents were brought inside the valves while the animal was feeding. The ears of *S. distincta* Cooper and Stehli are large, strongly convex, laterally extended beyond the lateral shell margin, and they bear a tuft of spines. Viewed from inside the pedicle valve, the ears are deeply concave and are separated from the main chamber of the valve by an elevated baffle that has a deep indentation near the midpoint, where it crosses the ear. This ridge curves around the ear to the beak, where, in some specimens, it forms a flattened plate. In the brachial valve a corresponding baffle extends from the cardinal process and curves around to cut off the flattened ear; it is highest where it crosses the ear. This crested part fits into the recess at the deep part of the ear of the pedicle valve. The delthyrium is almost obsolete in this genus, because the opening anterior to the beak is so broad. No trace of an elytridium was seen.

Inside the pedicle valve the adductor muscles were attached to a low ridge formed by the infolding of the valve along the exterior sulcus. The diductor scars are flabellate and were attached in the deep region on each side of the median ridge. Much of the inner surface of the pedicle valve, except that occupied by the muscles, is marked by rows of fine taleolae. These may be scattered or concentrated along the median ridge, in the lateral parts

of the umbonal chambers, and around the anterior ends of the diductors.

The most distinctive part of *Spyridiophora* is the interior of the brachial valve, with its peculiar spyridium that is intimately attached to the cardinal process. In its adult form the spyridium is an inverted, shallow cone with the apex directed anteriorly and supported by two subparallel plates. Posteriorly it is united to the cardinal process to form a single structure. In *S. reticulata* (King) the spyridium is not completely closed, but it is possible that old or truly adult specimens have not yet been found.

In young *Spyridiophora* two crescent-shaped plates form on each side of the median septum and gradually grow posteriorly and curve laterally so that they are strongly bowed with the concave side facing laterally. This forms a deep pit anterior to the cardinal process. The posterior ends of the adductor plates finally coalesce with the lateral ridges from the cardinal process to complete the pit. With continued growth the ventrad face of the plates flattens and impressions of the adductor muscles can be observed. The pit anterior to the cardinal process gradually fills with adventitious shell with increasing age, and finally is completely filled. The lateral ridges on each side of the cardinal process are fairly flat and in them on each side of the cardinal process appears an excavation which is, in effect, a socket that articulates with part of the lateral ridge around the posterior margin of the pedicle valve. In *S. reticulata* (R. E. King) the adductor plates remain separated but in *S. distincta* Cooper and Stehli they grow together to form the spyridium.

The spyridium of *S. distincta* is the most elaborately developed of described species. In this structure the crescent-shaped plates widen posteriorly and grow together anteriorly making a conical structure with an elongate opening anteriorly. On the inner sides of the spyridium the adductor scars can be seen clearly to consist of a posterior pair situated outside an anterior pair at the anterior side of the cone. The cardinal process is nearly imbedded in adventitious shell and a coating of adventitious shell thickens the inside part of the spyridium. The outside of the spyridium of *S. distincta* is crusted by endospines.

No specimens in early youth are available for study of the cardinal process. The youngest speci-

mens available show it to have been excavated anteriorly without suggesting the youthful stage of the Aulostegidae with its tentlike form. The young cardinal process of *Spyridiophora* is rather more like the productellid cardinal process, excavate anteriorly but narrowly bilobed posteriorly. In all specimens studied the cardinal process of the adult is bilobed, but the lobes are not widely divergent. The lophidium of the cardinal process is strongly developed but is broad rather than sharply carinate.

The median septum is long, slender, and elevated anteriorly. It originates well within the chamber under the spyridium and extends to about midvalve. The brachial ridges are narrowly looped and extend directly laterally. The median part of the brachial valve is more or less strongly sulcate, depending on the height of the fold, and this produces a deep median indentation. Strong endospines appear in a row just posterior to the subperipheral ridge along the anterior margin.

Several immature specimens of *Spyridiophora* preserve traces of the early attachment stages. Some of these traces are rings of spines which must have been attached around other brachiopod spines or crinoid stems or cirri. Some shells have the impress of a cylindrical object along the umbo, as described by Grant (1963). Attachment of the early shell was generally by part of the umbo with spiny anchors given off from the umbo and posterior margin. Several adult specimens give clear evidence that they had been living free of attachment. All scars of attachment or traces of early spines have disappeared and the beak shows no distortion. Furthermore, a few have ears with long spines in place, that, had they been attached, would have long since been ripped off. The conclusion is inescapable, then, that *Spyridiophora* was attached in the young and early adult stages and probably lived loose on the sea bottom or caught in a tangle of seaweeds, bryozoans, or other supports later in adulthood.

**STRATIGRAPHIC RANGE.**—The earliest appearance of *Spyridiophora* is in the Neal Ranch Formation and it occurs sparingly in the Lenox Hills Formation. It is present in the base of the Skinner Ranch Formation, and is fairly common although not well preserved in the thin-bedded sandy and conglomeratic limestones of the Poplar Tank Member; in the Sullivan Peak Member it is fairly common. The sponge reef in King's fossil bed (Taylor Ranch

Member of Hess Formation) has produced several specimens but the genus is not common at this level. In the Sierra Diablo it is present but uncommon in the basal part of the Bone Spring Formation. The stratigraphic interval of this species is, therefore, from Neal Ranch through Skinner Ranch, and hence, *Spyridiophora* is essentially a Wolfcampian fossil; but a holdover into the Cathedral Mountain was observed at USNM 721u where it is extremely rare.

*Spyridiophora compacta*, new species

PLATE 251: FIGURES 1-10

Medium size for genus, subrectangular in outline; wider than long, greatest width at hinge; width about twice length; ears prominent, extended. Sides narrowly rounded; anterior margin broadly emarginate.

Pedicle valve narrowly convex in lateral profile, broadly domed, median region sulcate in anterior profile; beak small, moderately swollen, lateral profile gently convex; umbonal slopes steep. Geniculation occurring 8 to 10 mm anterior to beak; angle of geniculation approximately 45°; geniculated area narrowly convex, marking anterior end of reticulation; trail long, about twice length of visceral disc; sulcus originating 3 to 5 mm anterior to beak, shallow on visceral disc but deepening at about point of geniculation and widening gradually to anterior margin to form broad V-shaped trough. Visceral disc coarsely reticulate; trail costate, with about nine costae on each side of sulcus, outermost costa of sulcus larger than others; flanks bounding sulcus rounded, sides steep. Ears moderately convex.

Brachial valve nearly flat, but umbonal region forming shallow pit; median region slightly and

MEASUREMENTS (in mm).—Thickness of holotype 6.0; of others, unmeasurable.

		brach- ial valve length	sur- face length	hinge width	maxi- mum width	height
USNM 715b						
149312a	12.7	10.4	16.0	11.6	17.3	7.0?
(holotype)						
149312b	13.0	?	25.0	16.8+	22.0	9.0
149312c	16.2	?	31.0	32.0*	32.0?	10.8
149312d	?	12.7	?	?	?	?
149312e	?	11.0	?	24.2	24.2	?

narrowly elevated to form low but distinct fold; region bounding fold gently concave; ears demarcated from rest of valve by low, oblique fold; ears nearly flat, with concentric markings only. Trail short, costate.

Interior unknown.

STRATIGRAPHIC OCCURRENCE.—Lenox Hill Formation (base).

LOCALITIES.—USNM 715b, 737u. The first locality is considered by Ross as in the Neal Ranch Formation. However, Lenox Hill type conglomerate interfingers into the strata, suggesting rather a Lenox Hills identification than Neal Ranch.

TYPES.—Holotype: USNM 149312a. Figured and measured paratypes: USNM 149312b-e.

DIAGNOSIS.—*Spyridiophora* of medium size, width twice the length, with poorly developed fold and moderately developed enlarged costa.

COMPARISON AND DISCUSSION.—The specimens on which this species is based come from hard, compact biohermal limestone. The low fold and moderately well developed outer costa make this species directly comparable to *S. distincta* Cooper and Stehli, another Wolfcampian species. It is proportionately narrower than *S. distincta*, as it has a length only half the width whereas the width of the other species is 2.5 times the length. The enlarged lateral costa is developed to about the same degree as that in *S. distincta* but is not so strong as the one in *Spyridiophora* species 1 (below) the chief distinction between them. *S. distincta* is very rare and is much larger than *S. compacta* and much more robust.

*Spyridiophora distincta* Cooper and Stehli

PLATE 251: FIGURES 12-31

*Productus gratiosus occidentalis* R. E. King (not Schellwien), 1931:71, pl. 14: figs. 1, 2 [not 3].

*Spyridiophora distincta* Cooper and Stehli, 1955:473, pl. 54: figs. 1-17.—Muir-Wood and Cooper, 1960, pl. 31: figs. 8-16.

Width nearly twice length, widest along hinge, ears strong, sides nearly straight, sloping medially; anterior margin broadly rounded, slightly emarginate medially; visceral disc of both valves finely reticulate, ears concentrically marked; visceral disc bearing short, curved, oblique, ornament spines; angle of geniculation about 75°; trail marked by about 9 costae, last one larger than the others and bearing a row of stout, rhizoid spines.

Costae bearing scattered ornament spines; umbo, umbonal slopes, ears, and posterior margin bearing stout, rhizoid spines.

Pedicle valve narrowly convex in lateral profile, visceral disc and trail gently convex; anterior profile broadly domed, bilobed, sulcus broadly V-shaped, separating lobes. Beak small, incurved, projecting slightly over brachial valve; umbo not showing scar of attachment. Umbo moderately swollen; geniculation originating about 10 mm from beak; umbonal slopes steep. Median region swollen; sulcus originating about 5 mm anterior to beak, shallow at origin but deepening to anterior margin, moderately deep from geniculated region to anterior margin. Flanks bounding sulcus rounded, lateral slopes steep but slopes leading into

sulcus only moderately steep. Ear large and moderately rounded.

Brachial valve nearly flat in profile; umbonal pit shallow, posterior to low poorly defined median fold which is best defined in anterior third. Region bounding fold, gently concave. Ears prominent, thin, delicate, demarcated from strongly reticulate visceral disc by narrow and prominent oblique groove. Geniculate part, short.

Pedicle valve interior with short, low median ridge in umbonal region; ridge across ears strong; interior with line of irregular endospines. Brachial valve with large conical spyridium enclosed on ventral side; lateral and subperipheral ridges, strong and prominent.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	half width	maximum width	height	thickness
USNM 701k							
124117	16.6	12.1	33.0	17.1	34.2	12.2	10.3
(holotype)							
124116a	15.0	11.6	29.0	14.35	28.7?	10.9	8.8
124116b	16.2	11.7	32.0	20.9	41.8	12.8	10.7
149316a	14.2	11.6	28.0	12.45	24.9	10.8	7.2
149316b	13.8	?	26.5	13.4	26.8	10.0	?

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (beds 2 through 14).

LOCALITIES.—King 93; USNM 701, 701d, 701h, 701k, 712z, 713h.

DIAGNOSIS.—Wedge-hinged, finely reticulate *Spyridiophora* with subdued fold but moderately developed sulcus.

TYPES.—Holotype: USNM 124117. Figured paratypes: USNM 124116a, b, e. Unfigured paratypes: USNM 124116c, d. Measured paratypes: USNM 124116a, b; 149316a, b.

DISCUSSION.—The moderate development of the fold and sulcus distinguish this species from *S. reticulata* (King) which has a deep sulcus and a strong fold. *Spyridiophora* sp. 1 is similar in proportions but has a longer trail and much more elaborately developed outer costa bearing a row of strong spines. It differs from *S. compacta*, new species, in size and in proportion of visceral disc to trail, the latter being longer in *S. compacta* than *S. distincta*. *Spyridiophora* sp. 1 approaches *S. distincta* in size and proportions but has a longer trail

and the distinctive, greatly swollen outside costa which is more strongly developed in this species than any of the others.

*Spyridiophora distincta* appears to be restricted to the Neal Ranch Formation and occurs at levels from bed 5 to bed 14. It is a rare species, only a few specimens having been taken from the several tons of rock dissolved, and only three specimens found loose on the outcrop.

#### *Spyridiophora reticulata* (R. E. King)

PLATE 231: FIGURES 32–34; PLATE 251: FIGURE 11; PLATE 252: FIGURES 1–57; PLATE 253: FIGURES 1–9, 11–36; PLATE 475: FIGURES 1–5

*Marginifera reticulata* R. E. King, 1931:89, pl. 22: figs. 3–10, *Spyridiophora reticulata* (R. E. King) Cooper and Stehli, 1955:472, pl. 53: figs. 1–17.

Moderately large, wider than long, length equal to about three-fifths width; widest at hinge, ears prominent; sides rounded; anterior margin narrowly emarginate. Ears narrowly rounded, not



greatly extended. Visceral disc of both valves coarsely reticulate, bearing short curved ornament spines; angle of geniculation approximately 90°; trail marked by 7 to 10 costae on each side of sulcus, last costa fairly swollen and enlarged. Median costae curving medially into deep sulcus. Rhizoid spines in row on enlarged outer costa, along posterior margin, and on umbonal slopes.

Pedicle valve narrowly convex in lateral profile, visceral disc gently convex to nearly flat, trail usually gently convex. Anterior profile strongly convex, strongly bilobed, both lobes narrowly rounded, profile indented deeply medianly. Beak small, retaining scar of attachment in some specimens; umbo somewhat narrowly swollen, slopes steep to ears; median region swollen. Sulcus originating on umbo within millimeter or two of beak, shallow at origin but deepening rapidly anteriorly and generally forming deep V-shaped trough. Flanks bounding sulcus narrowly rounded, steep slopes

leading into sulcus, precipitous anterior and lateral slopes.

Brachial valve in lateral profile forming nearly right angle, visceral disc nearly flat; umbonal region moderately depressed, concavity extending antero-lateral extremities and bounding low, subcarinate fold originating in umbonal depression, and elevating gradually anteriorly. Ears demarcated by poorly defined low ridge and abrupt cessation of reticulate ornament along oblique line; surface of ears gently concave, marked by concentric wrinkles parallel to lateral margin.

Pedicle valve interior with prominent median ridge formed by infolding of valve medially along line of sulcus; ridge across ears prominent. Brachial valve with moderately strong ridge extending across ears and around inner and anterior margins to die out at deep sulcus. Spyridium delicately formed, not strongly thickened, open anteriorly and ventrally. Brachial ridges indistinct.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	complete hinge width	height	thickness
YPM 11724 (lectotype)	?	11.3+	?	16.6*	?	?
USNM 702d						
149321	18.6	15.0	32.0	33.0	11.5	8.2
149323a	14.9	12.4	23.5	30.6*	9.7	6.3
149323b	16.0	13.3	25.0	31.4*	10.8	7.9
USNM 705r						
149325	14.0	11.4	24.0	23.0*	7.6	6.3
USNM 702e						
149334	14.0	12.9	18.0	21.2*	6.4	5.2
USNM 707d						
124118a	15.4	?	25.0	26.8*	9.3	?
124118b	?	11.5	?	18.0*	?	?
USNM 722-1						
152665a	16.4	?	29.0	34.0	11.4	?
152665b	16.5	?	27.5	31.2	12.0	?

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch, Poplar Tank, Dugout Mountain, and Sullivan Peak members), Hess Formation (Taylor Ranch Member), Bone Spring Formation.

LOCALITIES.—Decie Ranch: USNM 707a, 707g, 707-1, 707w, 713s, 715a, 727t, 727u. Poplar Tank: USNM 707ha, 707i, 708e, 713r, 729q, 741k. Dugout Mountain: USNM 700t, 730s. Sullivan Peak: King 226; USNM 705o, 707, 707b, 707d, 713c, 713d,

715f, 715j, 722h, 722j, 722-1; 727a, 731g, 733j, 739g. Skinner Ranch: King Tb; USNM 705r, 709a, 709z, 710r, 711d, 712p, 713n, 722m, 723h, 723-1, 723o, 726-1, 727b, 727f, 730o, 730r, 730v, 735f. Hess: USNM 709g. Taylor Ranch: USNM 702d, 702e, Bone Spring: AMNH 492, 591; USNM 728g, 728f.

DIAGNOSIS.—*Spyridiophora* with a subdued outer costa but a deeply sulcate pedicle valve, the sulcus originating close to the beak.

TYPES.—Lectotype (Cooper and Stehli, 1955:

473): YPM 11724. Figured paratypes: YPM 11727; T10056a, b. Figured hypotypes: AMNH 27932/2 and USNM 124118b, 149321a, b; 149325; 149327; 152665a-c; 153921; 154149a, b; 154230; 154229a, b; 154231a-o; 154232a; 154233a, b. Measured hypotypes: USNM 124118a, b; 149321; 149323a, b; 149325; 149334; 152665a, b.

COMPARISON.—R. E. King (1931:89) failed to name a type for his species. Eight cotypes were figured by him, but all of them are very poor and none shows all of the characters. In their description of the genus *Spyridiophora*, Cooper and Stehli fixed King's specimen YPM 11724 as lectotype. This specimen is fragmentary, preserving only part of the brachial valve, but it shows well the strong median fold and the prominent ear. The median fold indicates a deeply sulcate species and this inference is borne out by some of the other cotypes (T10056). Its coarsely reticulate pattern was another feature of importance that led to the selection of this specimen as lectotype although it was not complete. All the specimens figured by King under this name belong to the same species.

*Spyridiophora reticulata* resembles the other species in its great width compared to length but it differs from *S. distincta* Cooper and Stehli in having generally stronger costae on the trail, a coarser reticulate pattern on the visceral disc, and a much stronger fold and sulcus, the latter being the chief distinguishing character of the species.

*Spyridiophora* species 1 differs somewhat in proportions but is especially characterized by the swollen outside costa which is more pronounced in this species than any of the others. *Spyridiophora compacta*, new species, differs from *S. reticulata* in size and in finer costae on the trail and also in a less strong development of the median sulcus and fold.

DISCUSSION.—*Spyridiophora reticulata* is the commonest species of the genus in the Glass Mountains. It has the widest geographic range and also the longest stratigraphic range. It is especially common in the Lenox Hills area, but is not abundant. It is frequently seen on rock surfaces, especially in the thin-bedded and conglomeratic beds in the Poplar Tank Member between the Decie Ranch and Sullivan Peak members. The specimens in such occurrences are generally not good and can be extracted in reasonably good condition only with the greatest of difficulty. The vertical range of the species is from bottom to top of the Skinner Ranch Forma-

tion. In the eastern part of the Glass Mountains this is a rare species found sparingly in the Taylor Ranch Member of the Hess Formation. Here it occurs in the "sponge reef" just north of the Wolf Camp Hills (USNM 702d). The genus is extremely rare above the level of the Sullivan Peak Member or its equivalents and is only known as a few fragments (9 specimens from more than a ton of rock) in the lower part of the Cathedral Mountain Formation at USNM 721u.

### *Spyridiophora* species 1

PLATE 253: FIGURES 37-44

*Productus gratiosus occidentalis* R. E. King (not Schellwien), 1931:71, pl. 14: figs. 3a-c.

Known from pedicle valve only; transversely rectangular in outline, hinge forming greatest width; cardinal extremities extended and narrowly rounded; anterior margin broadly emarginate; beak small, swollen, protruding slightly posterior to posterior margin; umbonal slopes short and steep. Geniculation strong, occurring about 10 mm. anterior to beak (about one-third surface length); geniculate area narrowly rounded; trail long and gently convex in profile; surface roughly parallel to surface of visceral disc. Sulcus originating just anterior to umbo, deepening but not widening anteriorly and dividing trail into two lobate areas; flanks of trail bounding sulcus swollen. Lateral slopes of visceral disc marked by strong, spine-bearing costa thickening and elevating anterolaterally on outer slope of trail, thus setting trail area off from ears by thick, rounded barrier. Ears narrowly swollen and bearing strong erect spines.

Surface of visceral disc area strongly but finely reticulate; trail marked only by strong radial costae about 1 mm wide at margin and separated by troughs of nearly equal width. Scattered stout, erect spines appearing on costae and smaller ones on visceral disc.

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (bed 3 of Gaptank section).

LOCALITIES.—Schuchert locality 5d (= 1 mile south of Gaptank).

TYPES.—Figured specimen: YPM 12664.

COMPARISON.—This species differs from *S. distincta* Cooper and Stehli in being more strongly geniculate, in having somewhat finer costae on the

trail, and a much stronger lateral costa dividing the ear from the trail. It has a less strongly costate trail than *S. reticulata* (R. E. King) and a wider, shallower sulcus. It is wider and more strongly geniculated than *S. compacta*, new species. The lateral fold adjacent to the ear is more prominent on this species than that of the other described species.

**DISCUSSION.**—The specimen on which this species is based is said to have come from bed 3 of the Gaptank section, a position that places the genus well down in the Pennsylvanian, in beds of Canyon age. Inasmuch as no other specimens have been taken from the Gaptank elsewhere, nor has the genus been seen in the Pennsylvanian outside of West Texas, we became suspicious of a mistake in its age. We examined the type specimen very carefully and discovered a few fusulinids in the attached matrix. These were sent to Garner Wilde for examination and were pronounced (letter of February 8, 1967) to be of probable Wolfcampian age (*Leptotriticites* and *Schwagerina*). This does not solve the problem of where the specimen was found, but it does eliminate the Pennsylvanian as part of the range of the genus, and makes occurrence of *Spyridiophora* in the Gaptank Formation doubtful at best.

### *Spyridiophora* species 2

A species of *Spyridiophora* suggesting *S. reticulata* (R. E. King) was found in the Lenox Hills Formation at USNM 705. It is about 15 mm long and 26 mm wide, but the only pedicle valve is not complete. Reticulation is strong and the trail is strongly costate, having 9 costae, of which 6 are strong. The two inside costae have a strong "toe-in" toward the median line of the sulcus. The outer shell is preserved only on the ear and on part of the lateral slope showing the enlarged lateral costa, which is low but prominent. The visceral disc region is moderately inflated, as nearly as can be determined from the exfoliated specimen. The brachial valve is nearly flat and has a moderately strong median fold and fairly strong reticulation.

Compared to *S. reticulata* (R. E. King) the visceral disc appears to be more convex, the geniculation of the pedicle valve somewhat less abrupt, and the costation of the trail not quite so strong.

*Spyridiophora* should be expected high in the Lenox Hills Formation, as it appears in the Neal Ranch Formation and the overlying Skinner

Ranch Formation. The Lenox Hills specimens are more strongly costate than those from the Neal Ranch and are thus intermediate between *S. distincta* Cooper and Stehli and *S. reticulata*.

**TYPES.**—Described specimens: USNM 152666a, b.

### **AGELESIIDAE, new family**

Aberrant Aulostegacea having a subtriangular form, reduced interarea in the pedicle valve, a widely bilobed cardinal process, and strong adductor platforms.

Genus in West Texas: *Agelesia* Cooper and Grant, 1969.

This genus is restricted to the lower Cathedral Mountain Formation, where it has essentially the same distribution as *Institella*. Its relationships to other aulostegaceans remains obscure.

### **Genus *Agelesia* Cooper and Grant, 1969**

*Agelesia* Cooper and Grant, 1969:6.

Small, triangular to oval in outline, concavo-convex, commonly misshapen; maximum width usually anterior to midvalve; anterior commissure faintly uniplicate; brachial valve concave, with margins of brachial valve elevated above it. Surface of both valves covered by minute concentric wrinkles, that of brachial valve complicated by dimples corresponding to spines of pedicle valve, interrupting concentric ornament. Spines confined to pedicle valve, consisting of large rhizoid spines along margins and part way around anterior margin; ornament spines recumbent to erect and usually short.

Pedicle valve interior with posterior flattened to form indefinite palintrope or ginglymus?, cleft medially by triangular opening; triangular plate marked by low ridge beneath or ventrad of opening; muscle area with triangular adductor field elevated on platform; diductor scars elongate, located on side wall.

Brachial valve interior with large, widely bilobed cardinal process; adductor platform thickened and deeply recessed anteriorly; brevisseptum strong, distally elevated. Anterior margin marked by at least two rows of strong endospines.

**TYPE-SPECIES.**—*Aulosteges triangularis* [sic] R. E. King. (1931:94, pl. 27: figs. 1a, b [not figs. 2a, b, 3]).

**DIAGNOSIS.**—Small Productidina having triangu-

lar outline, indistinct palintrope and muscle platform in the pedicle valve, and strongly bilobed cardinal process in the brachial valve.

COMPARISONS.—*Agelesia* is most like *Giriasia* from the Sosio Limestone of Sicily. The two have a strong external resemblance and both have a strongly bilobed cardinal process. In spite of these obvious similarities they appear to be different in important details. The spine arrangement of *Giriasia* is not well known. It had small ornament spines on the pedicle valve like those of *Agelesia* but it had small slender spines on the brachial valve as well. Attachment spines on the lateral margin and umbonal region were somewhat larger in diameter than those of the ornament spines but seem not so numerous nor so thick as those of *Agelesia*. An important difference between the two genera appears at the apex of the pedicle valve of *Giriasia* which is provided with a fairly long and flat interarea which, however, is not divided by an opening of any sort. Thus, with only a few characters, the two genera prove to be different. The interior of the brachial valve of *Giriasia*, other than the bilobed cardinal process, is not yet known.

DISCUSSION.—This interesting genus is highly variable in form and outline, as might be expected in a shell that anchored at the beak and held itself stationary by supporting spines. Generally the outline is triangular but varies from nearly circular to elongate oval. Many misshapen specimens occur in the collection, abnormally elongated, narrowed, twisted, or otherwise deformed.

The prevailing ornament of both valves are the fine, concentric, wavy and usually laterally interrupted wrinkles. These generally do not extend completely across the valves but end before reaching one side or the other. Between the interrupted ends a new wrinkle is commonly inserted. The wrinkles on the pedicle valve are complicated by rounded spine bases and those on the brachial valve by dimples corresponding to the spine bases of the other valve. No trace of radial ornament was seen on either valve, but interrupted costae, produced by anterior growth at the front of a spine or spine base, occur on some specimens.

The spine bases of the ornament spines of the pedicle valve are small and rounded. Spines that arise from them are short, slightly curved toward the pedicle valve, and suberect on the posterior parts of the valve, but recumbent to prone on the

anterior parts. The latter condition may result from crushing, but most of the spines examined show no evidence of breakage. These ornament spines, concentrated on the shell body, seldom appear on the lateral slopes or umbonal region, where their place is taken by the thick rhizoid spines that anchor the valves.

The anchor spines form a thick brush on the lateral slopes from the beak to the anterior margin and at one time or another in the life of the shell covered the entire umbonal region. Anchor spines appear part way around the anterior margin in some specimens but no specimen was seen in which the spines appeared at midvalve on the anterior margin. Many anchor spines extend directly from their point of origin to the attachment surface, where they are deflected and grow along the surface for some distance. Some anchor spines are as long or longer than the valve, especially those anterolaterally placed, which have a long distance to grow to meet the surface of attachment.

The pedicle valve interior has many unusual features, especially those centering around the beak and the muscles. The beak varies from short and inconspicuous to long, narrow, and tapering. Just anterior to the beak is a narrow triangular opening into which the posterior of the brachial valve and the cardinal process fit. On each side of this opening is a smooth, flattened area that in some specimens ends against the lateral wall or in others extends some distance anterolaterally along the inside wall. In most specimens in which the two valves are in contact, the posterior edge of the brachial valve lies against this flattened area. In some specimens the flattened portion hangs over the valve interior and thus suggests a palintrope and interarea. But the fact that the brachial valve overlaps the smooth area rather suggests that it is a ginglymus. At any rate, it is a conspicuous and distinctive feature of this genus.

The triangular opening contains a plate beneath the surface of the flattened area, helping to articulate the two valves. It is attached to the sides of the triangular opening well below the surface and is strengthened below by callus deposited under it. The visible surface is marked by a median line that bisects the posterior angle of the plate and the anterior margin. This small ridge fits between the two lobes of the cardinal process, and the latter fits into the triangular opening. This is a sort of



articulation, and the outer margins of the brachial valve rest against the ginglymus and a shelf around, or part way around, the lateral wall of the pedicle valve.

The muscle area is unique in its form. The adductors were attached to a broad triangular platform in the apical part of the valve. In many specimens the platform is scarcely visible but in others it is strongly thickened and appears as a wall across the apical part of the valve. In still others, it is deeply excavated and appears as an elevated platform between the valve floor and the margin. In these specimens the valve floor under the adductor shelf is strongly granulose. The diductor scars are elongate and located outside the adductor platform on the sloping lateral wall. In old specimens, these have a thickened rim outlining the margin of the diductor scar. Most juveniles and young adults however show no trace of this large muscle scar. Anterior to the muscle scars for a short distance the shell is commonly granulose.

The brachial valve forms a lid over the pedicle valve that is depressed below the margins of the pedicle valve in many specimens. Large individuals from USNM 703bs commonly have a considerable part of the pedicle valve forming an elevated rim around the margins of the brachial valve. In many specimens the posterior margin of the brachial fits snugly against the beak area of the pedicle valve, completely obscuring the ginglymus.

The two most striking features of the brachial valve are the cardinal process and adductor platform. The cardinal process is unusual in its widely bilobed distal end. Each lobe bears a distal incision that usually is covered by shell material where the lobes unite. Occasional specimens show a tendency toward trilobation, which seems to be universal in the productid cardinal process. This median lobe is developed at the junction of the two lateral lobes but is rarely seen.

The cardinal process fits snugly into the triangular depression under the beak of the pedicle valve, apparently in close connection with the small plate partially filling the pedicle valve opening. So close is this junction that the median depression of the cardinal process is compensated on the pedicle valve by the development of a small ridge on the pedicle plate. This close union of the two valves helps to keep them in contact.

The adductor platform of the brachial valve is

also strongly developed. This appears as two lobate plates sloping laterally and nearly joined along the median line. Between the valve floor and these plates extends a deep reentrant, or cavity, into which the proximal end of the brevisseptum extends. This arrangement is strongly reminiscent of the adductor platform of *Echinosteges*. Not one of the specimens from any locality where this genus is found revealed individual muscle scars on the adductor platform. Presumably all the muscles were attached to the platform, because no scars were seen on the valve floor on each side of it.

In many old specimens an oblique ridge sets off an ear on the posterolateral extremities. This is evidently an ear baffle. The brevisseptum is low between the parts of the adductor platform but becomes elevated distally. At the distal extremity this septum is expanded and elevated, with the anterior edge commonly uneven or serrated.

The brachial ridges are preserved in a few specimens only. They originate at the anterolateral extremities of the adductor platform and descend anterolaterally to make a broad loop. These ridges are thus strophalosiid in their general form. Large and thick endospines appear on the lateral areas and on the anterior slope in front of the brevisseptum.

GROWTH.—The smallest specimens are nearly circular and are attached by their entire surface and further anchored by a ring of spines. Growth at the anterior margin was rapid and the small *Agelesia* soon became upright. Rhizoid spines are sent out from the sides to anchor the growing shell more strongly. After reaching an upright position, few spines are given off from the umbonal region.

### *Agelesia triagonalis* (R. E. King)

PLATE 231: FIGURES 1–31, 35–43; PLATE 255: FIGURES 1–44

*Aulosteges triagonalis* R. E. King, 1931:94, pl. 27: figs. 1a, b [only].

*Agelesia triagonalis* (King) Cooper and Grant, 1969:6, pl. 5: figs. 30, 31.

Small, triangular outline, narrow hinge but broad anterior; sides nearly straight to gently rounded; anterolateral extremities narrowly rounded; anterior margin rounded, truncate to emarginate. Surface of both valves marked by fine concentric and discontinuous wrinkles, pedicle valve bearing rounded spine bases, brachial valve

complicated by rounded, shallow dimples corresponding to spine bases of pedicle valve. Ornament spines short, suberect to recumbent; rhizoid spines long, stout, forming brush on the sides and postero-lateral extremities.

Pedicle valve fairly strongly convex and fairly even in convexity, posterior third somewhat more incurved; anterior profile of adults strongly domed, sides steep. Umbonal region narrowly convex, not greatly swollen. Median region inflated. Sulcus originating near midvalve, shallow, narrow, poorly defined in many specimens, in others indenting anterior margin but usually not deeply. Flanks

bounding sulcus not swollen; anterior slope steep; umbolateral slopes precipitous.

Brachial valve gently and unevenly concave, most concavity located near midvalve; anterior third somewhat flattened or slightly folded; sides sloping inward gently. Entire valve commonly depressed slightly below lateral margins of pedicle valve.

Pedicle valve interior with flattened and thickened rim, or ginglymus, of variable length and width on each side of beak, commonly extended anteriorly as slight submarginal shelf around inside. Adductor platform well developed only in adults.

Brachial valve interior with large bilobed

#### MEASUREMENTS (in mm).—

	<i>length</i>	<i>brachial valve length</i>	<i>surface length</i>	<i>hinge width</i>	<i>midwidth</i>	<i>height</i>	<i>thickness</i>
USNM 714w							
151520a	13.7	10.9	24.0	5.3?	15.3	8.7	6.9
151520b	14.3	12.0	25.0	3.0?	15.3	7.9	5.9
151520c	13.4	11.4	21.0	1.4?	13.8	6.6	4.5
151520d	11.9	10.5	19.0	1.9?	13.0	5.6	3.6
151520e	11.7	9.4	19.0	3.1?	12.8	6.7	4.5
151520f	9.7	8.9	15.0	3.4?	10.5	4.2	2.9
151520g	9.7	8.1	16.0	2.7?	11.0	5.2	3.9
151520h	9.4	7.8	15.0	2.4	10.4	5.7	4.8
151520i	11.0	9.8	14.0	2.7?	11.2	4.7	2.1
151520j	9.0	8.2	13.0	2.3?	10.5	3.9	2.0
151520k	9.9	8.8	12.0	2.4?	10.2	4.0	2.2
151520l	9.7	9.1	12.0	3.0?	10.4	3.0	1.9
151520m	8.6	8.0	10.0	3.6?	9.6	2.9	1.8
151520n	7.7	6.5	9.0	?	8.1	2.7	1.5
151520o	6.5	?	8.0	?	6.3	2.5	1.7
151520p	6.9	?	8.0	?	6.5	1.9	1.0
151520q	14.8	12.7	19.5	?	17.5	6.3	4.7
151520r	13.9	?	20.0	?	15.2	7.4	?
151520s	11.6	9.3	22.0	4.9?	12.9	8.4	6.4
USNM 703bs							
151516a	16.6	13.7	24.0	5.6?	18.4	12.0	7.3
151516b	14.8	13.0	23.0	5.4?	16.9	8.6	5.7
151516c	14.8	12.7	18.0	?	15.2	5.7	4.1
151516d	14.5	11.3	19.5	4.5?	14.3	6.4	4.3
151516e	12.7	11.4	18.0	5.0?	14.7	6.5	4.0
151516f	12.0	10.7	16.0	?	14.7	5.6	3.2
151516g	13.2	12.0	18.0	?	14.0	6.3	4.1
151516h	11.4	9.9	16.0	?	12.1	5.0	3.3
151516i	11.8	11.0	14.0	?	12.4	3.6	2.4
151516j	10.7	9.6	12.0	?	12.1	3.8	2.3
151516k	11.0	10.4	15.0	?	12.0	5.1	3.0
151516l	10.7	9.7	15.3	?	11.0	4.8	3.3
151516m	11.0	9.1	15.0	?	11.6?	4.0	2.6
151516n	8.9	?	11.0	?	9.9	2.7	1.8
151516o	7.7	7.2	9.0	?	7.5	2.6	2.2
151516p	10.5	8.7	16.0	?	11.6	6.5	4.4
151516q	13.9	11.1	22.0	?	15.4	8.7	6.0

cardinal process having widely divergent lobes; adductor platforms subtriangular in outline, strongly elevated and thick. Brachial ridges seldom developed. Posterolateral baffles rarely well developed.

**STRATIGRAPHIC OCCURRENCE.**—Bone Spring Formation (middle), Skinner Ranch Formation (Sullivan Peak Member), Cathedral Mountain Formation (and Wedin Member).

**LOCALITIES.**—Bone Spring: AMNH 658. Sullivan Peak: USNM 707b. Cathedral Mountain: King 231 = 122; USNM 703b, 703bs, 708, 712o, 721u, 723n, 723u, 727o, 727w, 727x, 731b, 731n, 741s. Wedin: USNM 700-1, 700x, 710d, 714w, 717e, 723v, 727p.

**DIAGNOSIS.**—Triangular with length slightly less than maximum width, fine wrinkles, and broad lateral expansion of pedicle valve around the brachial valve.

**TYPES.**—Holotype: YPM 11883. Figured paratype: T11014. Figured hypotypes: USNM 151514a, b; 151515a; 151516b, c; 151520b, d; 153834a-g; 154144a-d, g, i, j; 154145a-c; 154146a-d; 154147a, b; 154148. Measured hypotypes: USNM 151516a-q, 151520a-s.

**THE NAME.**—The specific name of this species was spelled by King in two ways: *triagonalis* and *trigonalis*. The former spelling appears in the heading of the description and the index; the other name appears in a faunal list and in the legend to his (1931) plate 27. Both spellings are permissible for a triangular object, consequently, we select the first spelling because it appears at the heading of the description. This spelling is also used by Branson (1948:297) in his index of Permian fossils.

**COMPARISON.**—No other species of this genus is known to which this one may be compared. Its triangular form and beak region are so unusual that it cannot be confused with any other of the attached productids.

**VARIATION.**—This species is highly variable probably due to its attached habit. It lived cemented to a variety of shells, bryozoans and other objects. When living in an unfavorable position it may be misshapen and distorted so that some are short and wide and others long and slender. The well-formed, large individual is generally moderately convex and the brachial valve moderately concave. Many specimens, however, are short, narrowly curved in profile, and have thick shells. These are similar to

the type specimen, which seems to represent a thickened adult individual that was unable to attain full development. This type is especially common at USNM 714w. More normal specimens are found at USNM 703bs, a place that represents a bioherm in which this species is abundant and well preserved. Many of these specimens are well formed and normal in all respects.

**LOCALITY AND STRATIGRAPHIC HORIZON OF THE TYPE SPECIMEN.**—The type specimen is listed as coming from King locality 231: "Leonard or uppermost Hess: Limestone containing chert pebbles directly below Leonard shale on south face of Leonard Mountain; same as locality 122." The latter locality is recorded as: "Hess or Leonard: Limestones below lower Leonard shale on Leonard Mountain, section 17." This is an ambiguous definition because it is not clear whether the Leonard shale referred to is the lowest shale on the Mountain. According to R. E. King's locality map this locality is the same as our localities 727m and 727n and, therefore, from the *Institella* beds of the Cathedral Mountain Formation rather than from the Hess.

The species appears to have a restricted stratigraphic range but a fairly wide geographic distribution. It occurs in abundance in the Wedin Member on Dugout Mountain and on the west side of the Lenox Hills where it is attached to *Institella*, *Enteleles*, and other shells, and grew in the thick masses of bryozoans of which some of the Wedin limestone is composed. In the eastern part of the Glass Mountains this species is most abundant near the Old Word Ranch where it is concentrated in a single bioherm of massive, dove-colored limestone (USNM 703bs).

### SCAPHARINIDAE, new family

Small elongate elliptical shells without an interarea; cardinal process small; lateral ridges strongly developed.

Genus in West Texas: *Scapharina*, new genus.

This family is established for small, uncommon shells occurring in the Guadalupian of the type region. Their distinctive character is in loss of the interarea. They are thus aberrant and because of their attached habit are regarded as developing from the Aulostegacea.

*Scapharina*, new genus[Greek *scaphe* (a ship)]

Small, elongate-elliptical in outline, deeply concavo-convex in profile, anterior commissure strongly concave in ventral direction; pedicle valve strongly and narrowly umbonate, beak small; no interarea, ears prominent. Surface varying from smooth to covered by thin, scaly lamellae. Spines few, confined to pedicle valve and all rhizoid or attaching spines.

Pedicle valve interior with deep umbonal chamber, usually with muscle scars lightly impressed and not differentiated, but some old specimens with low muscle platform; ear baffles usually strongly developed.

Brachial valve with strong submarginal rim extending from cardinal process around inside margin of entire shell; cardinal process small, short-shafted, usually with myophore directed posterodorsally and supported by lateral growths, forming platform; myophore very narrow, fitting into narrow beak of opposite valve. Adductor field narrow, elongate; brevisseptum delicate, low. Brachial ridges, short, narrow, slightly thickened, reaching to or slightly beyond midvalve. Endospines few.

TYPE-SPECIES.—*Scapharina rugosa*, new species.

DIAGNOSIS.—Small Aulostegacea having a few, strong rhizoid spines, deeply concavo-convex shells, narrowly elongate outline, and smooth to lamellose exterior.

COMPARISON.—This is one of the peculiar attached shells occurring in the Late Permian. It suggests *Xenosteges*, with which it was at first confused. It differs in not having an interarea, in having narrowly compressed and elongate valves, and in having a very small cardinal process rotated somewhat on the brachial valve hinge to face in a posterodorsal direction to fit into the narrow umbonal chamber of the pedicle valve. This genus is unlike the hereralosiids in lacking any ornament spines or teeth in the pedicle valve. The growth habit and obsolescence of the interarea suggest *Agelesia* Cooper and Grant (1969), but the ornament and pedicle beak of the latter is unlike *Scapharina*, and the cardinal process and other structures of the brachial valve are totally unlike.

DISCUSSION.—We do not have any specimens attached in their growth position, but it is clear from the position and direction of the spines that

they must have been for attachment. Most of the spines, which are generally broken, are directed posteriorly or down in the growth position when attached by the beak. Generally no cicatrix can be seen, but small short spines often appear on the umbo, clear evidence of attachment. Large spines on the shell body of both species are oriented to indicate that they too helped to anchor the shell to its base.

*Scapharina rugosa* has an extremely rough surface and in some specimens the surface is patchy. The true nature of the scaly lamellae has not been ascertained because the silicification is too coarse. By analogy with *Xenosteges*, which has the same kind of surface preservation, the surface must have been lamellose in this species.

The beak of the pedicle valve is interesting because of the strong overhang of the brachial valve beak. The hinge is narrowed to disappearance, and, as a consequence, the interarea has also disappeared. The opening in the beak is closed by the posterior side of the cardinal process. The ears of the pedicle valve are strongly developed and prominent inside and outside. On the inside they are demarcated by a strong oblique ridge or shelf that overhangs the interior in some specimens. We have been unsuccessful in determining the musculature, which is not impressed in recognizable degree in the umbonal chamber of *S. rugosa*. A low platform in the apical part of *S. levis*, however, indicates their position, if not their pattern.

The brachial valve of this genus is characterized by a very small, delicate, laterally compressed cardinal process. The process, however, is modified by the strong interior convexity of the valve. It is rotated to face posterodorsally and fits into the narrow part of the beak of the pedicle valve, which it effectively closes by a narrow lophidium. The cardinal process in side view is long and narrow and at the beak is perched on a thickened platform that surrounds the shaft and extends almost to the myophore.

Extending laterally from the platform carrying the cardinal process is a thick but low ridge that crosses anterior to the ears to gain the side just inside the margin, and then extends anteriorly and medially at the anterior to join the branch from the other side. This forms a low wall around the entire valve, just inside the margin.

The adductor field is long and slender and, in



some specimens, moderately thickened; but in many the scars are indistinct. In a few individuals the brevisseptum is anteriorly moderately high, but, in most, it is low and inconspicuous. The brachial ridges are very slender and are confined to the posterior half. A few endospines are present at the anterior of some valves.

This genus is rather rare in the Capitan and Bell Canyon formations and has not been seen in the lower part of the Guadalupian or in the Leonardian.

*Scapharina levis*, new species

PLATE 237: FIGURES 1-8, 21-55; PLATE 238: FIGURE 19

*Productus? pileolus* Girty (not Shumard), 1909:270, pl. 12: figs. 8-12, 14, 15 [not 13 (= *Heteralosia?*); not pl. 29: figs. 5-7 (= *Scapharina rugosa*, new species)].

Small for genus, outline variable, subcircular to subtrigonal; hinge narrower than midwidth; sides gently rounded; anterior margin strongly rounded; anterior commissure with gentle ventrad fold. Beak small and incurved over brachial valve umbo; no interarea. Ears fairly strong, rounded. Rhizoid spines few, mostly posterior but occasionally one or more at or near midvalve. Surface of both valves marked by concentric growth lines.

Pedicle valve strongly and fairly evenly convex, most convex medially and umbonally; anterior profile smooth, narrow dome with steep sides. Umbonal region narrowly swollen, steep umbonal slopes, swelling passing into tumid median region. Anterior and lateral slopes steep. Ears rounded but well demarcated.

Brachial valve deeply concave medially and with sides sloping inward laterally and anteriorly; ears flattened and deflected. Umbo rounded, swollen.

Pedicle valve interior with narrow but strong, oblique ear baffles; muscle region somewhat thickened in old shells.

Brachial valve interior with very small, narrowly compressed cardinal process on thin and narrow platform; submarginal rim narrow, not strongly thickened but complete; brachial ridges long, reaching to midvalve, slightly thickened. Endospines low, scattered anterior to midvalve.

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler, Pinery, Rader, and Lamar members), Capitan Formation.

LOCALITIES.—Hegler: AMNH 635; USNM 731, 732a, 740c. Pinery: AMNH 375, 397; USNM 733.

MEASUREMENTS: (in mm).—

	length	brach- ial valve length	mid- width	hinge width	height	thick- ness
USNM 738b						
152658a	8.5	6.9	7.5	5.4	3.6	1.9
152658b	8.4	7.3	7.8	4.8	3.7	2.1
152658c	8.2	7.0	7.3	5.0	3.7	1.5
152658d	7.4	6.3	6.3	3.7	3.2	1.3
152658e	6.5	5.5	5.8	3.7	3.5	1.7
152658f	?	6.7	6.9	3.9	?	?
152659	8.1	6.2	7.8	4.1	3.7	2.3
(holotype)						

Rader: USNM 725f, 725g, 740a, 740i, 740j. Lamar: AMNH L-3, 37, 38, 430; USNM 725e, 728p, 738b. Capitan: USGS 2926 green; USNM 725k, 738a, 740, 740-1, 750a.

DIAGNOSIS.—Large *Scapharina* with smooth shell surfaces.

TYPES.—Holotype: USNM 152659. Figured paratypes: USNM 152658a-c, f; 149223d, e, g; 154224a, b. Measured paratypes: USNM 152658a-f. Unfigured paratypes: USNM 149223a-c, f; 152658d. Measured paratypes: USNM 152658a-f.

COMPARISON.—Distinguished from *S. rugosa*, new species, by its larger size, more circular outline, and smooth shell surface.

DISCUSSION.—This species is uncommon, found in abundance only at USNM 738b. The interior presents some differences from that of *S. rugosa*, new species, such as thickening of the muscle region of the pedicle valve. The cardinal process of the brachial valve is very small and the submarginal rim very delicate but, nevertheless, complete. The posterior platform is not greatly thickened.

*Scapharina pileolus* (Shumard)

*Productus pileolus* Shumard, 1859:291; 1860:389.

In the absence of Shumard's actual types, this is another species that cannot be established with certainty. It is clear from Girty's (1909:270) discussion of Shumard's description that the species belongs to our new genus *Scapharina*. From Shumard's description the generic characters seem quite clear. One note of confusion, however, is that Shumard's reference to his single specimen is as a "dorsal valve." Girty questions this reference and interprets the description as referring to a pedicle or

ventral valve. Actually the specimen may have been either, and it is now impossible to tell which. Shumard may have been right in calling the specimen a dorsal valve because this valve, seen from the interior is also strongly convex and arched. Shumard's observation of a "projecting band or rim, which is rounded and extends to the cardinal edge" may refer to the prominent subperipheral band of the brachial valve. On the other hand, his statement that the beak projects beyond the "cardinal border" suggests that he really had a pedicle valve.

In view of this uncertainty and the impossibility of relating his vanished specimen to any of our species makes it necessary to leave his species name as a *nomen dubium*.

*Scapharina quadrata*, new species

PLATE 237: FIGURES 13-20; PLATE 238: FIGURES 1-18

Large for genus, wider than long, hinge about equal to midwidth; sides moderately rounded; anterior narrowly rounded; anterior commissure with broad ventral fold; beak small, strongly incurved over umbo of opposite valve; no interarea. Ears prominent, slightly auriculate. Surface of both valves nearly smooth but with occasional patches of lamellae.

Pedicle valve fairly strongly and evenly convex in lateral profile, strongly and narrowly domed in anterior profile. Umbonal region prominent, narrowly swollen; median region strongly tumid, anterior and lateral slopes very steep.

Brachial valve deeply concave, all slopes descending steeply toward midvalve; ears flattened and deflected toward the pedicle valve.

MEASUREMENTS (in mm).—Thickness unmeasurable.					
	length	brach- ial valve length	mid- width	hinge width	height
USNM 731					
152660a	6.9	?	6.5	5.3	3.7
(holotype)					
152660b	7.2	?	6.7	6.0*	3.7
152660c	?	7.2	8.7	7.6	3.0
152660d	?	6.7	7.1	6.2	?
152660e	?	6.0	7.3	7.1	3.4

Pedicle valve interior with strongly developed oblique ear baffle. Brachial valve interior with small cardinal process on low platform; submarginal ridge low and complete, fluted on inside of some specimens.

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler Member).

LOCALITIES.—USNM 731, 732a.

DIAGNOSIS.—Smooth *Scapharina* with wide hinge.

TYPES.—Holotype: USNM 152660a. Figured paratypes: USNM 152660b-e, 154225a, b.

COMPARISON.—This species is about the same size and appearance as *S. levis*, new species, but it has a wider hinge and is generally more rotund.

*Scapharina rugosa*, new species

PLATE 238: FIGURES 20-42; PLATE 239: FIGURES 1-56

Small, elongate elliptical outline, narrowly concavo-convex in section, sides rounded and anterior margin narrowly rounded. Maximum width near midvalve; hinge narrower than midwidth; ears prominent, forming nearly right angle or obtuse. Beak small and narrowly compressed, over hanging brachial valve hinge margin. Surface of both valves, with lumpy patches thought to be formed of scaly lamellae.

Pedicle valve strongly convex in lateral profile, with maximum convexity at midvalve; anterior profile narrowly rounded and domed, with steep and precipitous sides. Umbonal region narrowly swollen, swelling continuing and enlarging to midvalve; all slopes swelling and enlarging to midvalve; all slopes steep.

Brachial valve deeply concave, maximum depth extending from umbonal region nearly to front margin, there deflected dorsally; sides descending steeply; ears flattened.

Pedicle valve interior with strong, oblique ear baffles but with muscle scars poorly impressed. Brachial valve interior with strong submarginal ridge, poorly developed brachial ridges and brevi-septum; cardinal process very small and narrow, with a strongly developed, posteriorly narrowing platform.

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler, Pinery, Rader, McCombs, and Lamar members).

LOCALITIES.—Hegler: AMNH 635; USNM 731, 732a, 740c, 740d. Pinery: AMNH 528, 397, 401;

## MEASUREMENTS (in mm).—

	length	brach- ial valve length	mid- width	hinge width	height	thick- ness
USNM 731						
152657a	7.8	6.9	6.8	4.4	5.0	2.7
152657b	7.1	?	5.6	4.2	3.5	?
152657c	7.0	5.8	5.5	4.6	3.5	1.7
152657d	7.1	5.9	5.9	4.4	3.8	2.0
(holotype)						
152657e	6.3	5.5	5.7	4.2	3.2	1.5
152657f	?	6.5	5.3	3.8	?	?

USNM 725h, 725i, 725n, 736, 748. Radar: AMNH 403, 404, 410; USNM 725f, 725g, 740a, 740i, 740j, 725o. McCombs: AMNH 385. Lamar: USNM 738b.

DIAGNOSIS.—Narrowly elongate *Scapharina* with rough surface.

TYPES.—Holotype: USNM 152657d. Figured paratypes: USNM 152657a-c, e, f; 154226a-f; 154227 a-h; 154228a, b. Measured paratypes: USNM 152657 a-c, e, f.

COMPARISON.—Distinguished from *S. levis*, new species, by its elongate and narrow form and the rough surface.

DISCUSSION.—The lamellose surface is developed to an extreme degree in some specimens from the Rader Limestone (USNM 725f). Both valves are enormously thickened. A few specimens of this species develop a squarish form and some have retarded lamellae. Specimens are too few to make sure if these variations indicate specific differences or simply variation.

### Family RHAMNARIIDAE Muir-Wood and Cooper, 1960

Aberrant Aulostegacea lacking an elytridium but usually with an interarea on the pedicle valve; cardinal process strongly bilobed in the young, tri- or quadrilobed in the adult; pedicle valve with small apical septum in the young; spines abundant on both valves.

Genera in West Texas: *Ramavectus* Stehli, 1954; *Rhamnaria* Muir-Wood and Cooper, 1960; *Spuriosa*, new genus.

*Rhamnaria* is one of the most abundant genera in the Glass Mountains. It is common also in the Guadalupe Mountains but rare in the Sierra Diablo.

*Ramavectus* is rarer than *Rhamnaria* and not the Wolfcampian of the Glass Mountains and Sierra Diablo.

*Spuriosa* is a rare and obscure new genus from well understood. It was first defined from the brachial valve only.

### *Spuriosa*, new genus

[Latin *spurius* (false)]

Small, umbonally attached, spines on pedicle valve, none on brachial valve. Pedicle valve strongly convex; brachial valve concave; spines on ears rhizoid, those on body protective. Interarea vestigial or absent.

Pedicle valve interior with muscle area large, not well defined; old shells with short median myophragm at apex. Teeth absent, articulation effected by hinge margin and cardinal process.

Brachial valve with primitive widely bilobed cardinal process, each lobe cleft; cardinal process overhanging muscle region, reentrant more or less deep; cardinal process not supported, median septum near midvalve, terminating proximally within adductor field.

TYPES-SPECIES.—*Spuriosa circularis*, new species.

DIAGNOSIS.—Small attached productids with exterior details like *Heteralosia* but with a primitive, broadly bilobed cardinal process.

COMPARISON.—*Spuriosa* most nearly suggests *Costellarina* Cooper and Muir-Wood (1967; for *Costellaria* Muir-Wood and Cooper, 1960) which has the same structure in the dorsal valve as *Spuriosa* but differs in having a costellate exterior.

DISCUSSION.—The exterior aspect of this genus is like that of *Heteralosia*, but the two differ in interior details, especially the form of the cardinal process. The broadly bilobed process suggests the cardinal process of the Productellidae but differs in being so strongly excavated anteriorly that it overhangs the shell, as in the young of *Rhamnaria*. The median septum of *Spuriosa* does not extend posteriorly to help support the cardinal process, nor is there a thickened platform to strengthen the posterior, as in the Productellidae.

*Spuriosa* is a rare shell; we have it from only two localities, one in the Neal Ranch Formation in the Glass Mountains (USNM 701) and the other in the Hueco Formation in the Sierra Diablo (USNM 728d), represented there by poor material.

*Spuriosa circularis*, new species

PLATE 194: FIGURES 1-15

Small, subcircular in outline, width slightly greater than length; widest at midwidth; cicatrix of attachment small. Sides and anterior margin strongly rounded. Interarea short and curved. Spines on pedicle valve numerous, all about same size, well scattered on body and slopes but concentrated at ears. Pedicle valve with strong concentric wrinkles, especially at ears, and with scattered dimples.

Pedicle valve strongly convex in lateral profile, somewhat more sharply convex in anterior profile; umbonal region moderately swollen, extending posterior to hinge only small distance. Ears not prominent; brachial valve moderately concave, deepest near anterior; margins deflected moderately in dorsad direction. Ears not well differentiated.

Interior of pedicle valve with structures not differentiated. Interior brachial valve with stout median septum reaching beyond midvalve; cardinal process, large and bilobed.

MEASUREMENTS (in mm).—From locality USNM 701, specimens 153490a (holotype) and b, respectively: length 7.0, 6.6; brachial valve length 5.5, 6.0; maximum width 7.0, 7.0; hinge width 6.4, 4.5; thickness 3.4, 2.3.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (top 15 feet of King's bed 2).

LOCALITY.—USNM 701.

DIAGNOSIS.—*Spuriosa* nearly circular in outline with large bilobed cardinal process.

TYPES.—Holotype: USNM 153490a. Figured and measured paratype: USNM 153490b.

COMPARISON.—No other species of this genus now is known. A second species is indicated, however, by two specimens from the Hueco Formation (USNM 728d). These are very small and do not preserve identifiable specific characters.

Genus *Ramavectus* Stehli, 1954

*Ramavectus* Stehli, 1954:327.—Williams et al., 1965:H492.

Large, concavo-convex, brachial valve flattened posteriorly, geniculated anteriorly, bounding fairly deep visceral cavity; attached when young but probably living loose when adult. Pedicle valve strongly convex, short interarea and narrow hinge. Ears small; surface of both valves spinose, pedicle valve with thick brush of slender rhizoid spines on

ears, umbonal slopes, and posterior margin; body spines in two sizes: long, stout, recumbent spines and longer, slender, recumbent spines. Spines located at anterior end of long bases giving shell appearance of interrupted costellation. Brachial valve spines long and slender, fairly uniform in size.

Pedicle valve interior with small delthyrium rarely modified by elytridium; diductor scars large and flabellate, surrounding elongate, but subdued, adductor field.

Brachial valve with long, erect or curved cardinal process having grooved shaft with narrow, bilobed or trilobed myophore. Lateral ridges strong and narrow; buttress plates, thick, divergent, uncovered throughout life. Adductor field not thickened, small and dendritic. Brevisseptum long but low and sharp. Anterior slopes marked by short, thick endospines.

TYPE-SPECIES.—*Ramavectus diabloensis* Stehli (1954: 327, pl. 23: figs. 3, 4).

DIAGNOSIS.—Large Rhamnariinae with strong buttress plates in all stages of growth.

COMPARISON.—*Ramavectus* is similar externally to *Rhamnaria*, *Juresania*, *Bilotina*, and *Kochiproductus*. Similarity to *Rhamnaria* is seen in the presence of two sizes of ornament spines, a variably developed interarea, and a similarly developed brachial interior. Differences appear in the narrower and more elongated cardinal process, the great development of the buttress plates, and absence of a small median septum in the pedicle valve.

The exterior of *Juresania* and *Ramavectus* are similar, but the former has a more consistently scarred umbo and nearly parallel buttress plates that commonly are partly or completely covered in late growth stages. *Bilotina* is similar in appearance to *Ramavectus* externally but the interior is unknown.

Large specimens of *Ramavectus* strongly suggest *Kochiproductus* but they have an interarea which *Kochiproductus* lacks and the buttress plates of the cardinal process of *Ramavectus* are not covered as in *Kochiproductus*.

DISCUSSION.—Study of this genus is complicated by presence with it in the Bone Spring Limestone of a species of *Rhamnaria*. Small *Ramavectus* are difficult to separate from *Rhamnaria* by exterior examination but the presence of a small median septum in the pedicle valve is the best evidence for *Rhamnaria*. Externally, the two genera are very similar because they both have on the ears and umbonal slopes a tangled brush of rhizoid spines



by which they were attached. They also possess two kinds of ornament spines. The thinner, longer, and more delicate spines lie very close to the surface and are recumbent. The larger spines have a variable angle of divergence from the valve surface but, although larger than that of the small spines, it is small, and they too may be called recumbent. The one known species attained enormous size and specimens probably broke from their moorings in early adulthood to live loose on the sea bottom.

The interarea of the pedicle valve is generally small. It is larger than most ginglymoid hinges and is not likely to be confused with that structure. The interior of this valve is usually devoid of conspicuous elements. The musculature is lightly impressed and the anterior and lateral parts are covered by small, stubby taleolae.

The cardinal process and associated plates are of most interest in this genus. The young cardinal process has two separated lobes that unite with continued growth, but the initial separation is recorded in the deep grooving of the shaft. The myophore is usually trilobed, with a triangular median lobe closely united with two elongated, narrow lobes on each side that overhang the median lobe in some specimens but are well separated in others. The base of the shaft has four plates; the two lateral ones are strong, narrow, lateral ridges like those of many other productid genera, whereas the anterior two are buttress plates. These are usually strongly divergent but are nearly parallel in some specimens. They usually taper to the posterolateral margins of the adductor field where they disappear. Throughout the life of the animal these ridges are unmodified except for strengthening with growth. The animal does not fill them with callus or engulf them, as in *Buxtonia*, *Juresania*, *Kochiproductus*, and a few other genera. The brevisseptum usually dies out before reaching the base of the cardinal process and is a very feeble structure for such a large shell. The anterior slope and lateral areas outside the visceral region are covered by numerous small, stubby taleolae.

*Ramavectus diabloensis* Stehli

PLATE 256: FIGURES 15–24; PLATE 257: FIGURES 3–21; PLATE 258: FIGURES 27–29

*Ramavectus diabloensis* Stehli, 1954:328, pl. 23: figs. 3, 4.

Large, elongate oval in outline, hinge much narrower than midvalve, ears small, obscure.

Greatest width anterior to midvalve; sides rounded; anterior margin broadly rounded. Ears with brushes of fine rhizoid spines; body having recumbent spines of two sizes: stouter, shorter ones having a length of about 8 mm, and finer spines measuring more than twice this length. Spine bases distant, elongated, and simulating costellae, about 4 to 6 of each size per 10 mm on anterior slope of lectotype.

Pedicle valve strongly but unevenly convex in lateral profile, region slightly posterior to midvalve having greater convexity, anterior flattened and umbonal region curved. Anterior profile strongly domed, with steep slopes. Umbonal region strongly curved, narrowly swollen; venter strongly swollen, trail somewhat flattened and forming long, fairly steep slope. Sulcus originating on anterior side of umbonal region, narrow, shallow, flattening toward midvalve and disappearing on large adults anterior to midvalve. Flanks rounded and steep. Ears small, poorly defined, obtuse. Delthyrium with vestigial elytridium.

Brachial valve flatly concave in posterior two-thirds, moderately geniculated in anterior third; deepest in anterolateral regions at base of anterolateral slopes. Lateral slopes steep. Umbonal region depressed, bounded by two lateral, posteriorly convergent folds and posterior end of median fold originating just anterior to umbonal depression. Fold low, narrow, subcarinate, best defined in posterior half but broadening and flattening anteriorly.

Pedicle valve interior with broadly flabellate diductor scars but poorly differentiated adductor field. Young with minute median septum.

Brachial valve interior characterized by narrow and elongated cardinal process, usually erect but in some specimens recurved dorsally to hang over hinge. Buttress plates strong, usually widely divergent; young without buttress plates. Adductor field not thickened, lightly impressed.

MEASUREMENTS (in mm).—Thickness unmeasurable.

		brach- ial valve length	sur- face length	hinge width	maxi- mum width	height
USNM 728c						
148959a	72.6	?	112.0	36.3	63.0	30.0?
148957a	?	43.0	?	36.4	50.0*	?
148957b	19.0	?	28.0	15.7	24.6	8.8
149450a	?	20.5	?	17.9	26.5	?

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation, Skinner Ranch Formation (base).

LOCALITIES.—Bone Spring: AMNH 625. Skinner Ranch: USNM 728e.

DIAGNOSIS.—Very large *Ramavectus* with scattered body spines, dense brush of fine spines on the ears, and buttress plates in all adults.

TYPES.—Lectotype (herein designated): AMNH 27308/1:1. Figured hypotypes: USNM 148957a, b; 148959a, b; 149450a, b; 154210a, b, j-l. Measured hypotypes: USNM 148957a, b; 148959a; 149450a.

COMPARISON.—This is the only species of the genus known. It is suggestive of *Rhamnaria grandis*, new species, but has a shallower sulcus, and different development of the cardinal process, which is less elongated and has the lobes not separated.

TYPE-SPECIMEN.—Stehli described and illustrated two specimens of the species but failed to select a holotype. We therefore select the complete valve on plate 23, figure 3 (Stehli, 1954) as the lectotype. This shows the large size, good outline, compressed cardinal process, and spines.

DISCUSSION.—Two features of this species are outstanding: the size and the cardinal process. Both of these make problems in classification and identification. The large specimens simulate *Kochiproductus* in the incurved and swollen beak and the well-buttressed cardinal process. The great length and often curved nature of this process is probably a result of the size and rotation of the pedicle valve on the hinge. Close examination of *R. diabloensis* of large size reveals an interarea on the pedicle valve and the fact that the median septum of the brachial valve does not invade the space between the buttress plates, as in *Kochiproductus*. Furthermore, none of the specimens of *Ramavectus* shows any adventitious shell covering or hiding the buttress plates, as often happens in *Kochiproductus*.

### Genus *Rhamnaria* Muir-Wood and Cooper, 1960

*Rhamnaria* Muir-Wood and Cooper, 1960:119.—Williams et al., 1965:H458.

Medium to large, plano- to concavo-convex; cicatrix of attachment on pedicle valve small; hinge wide but generally narrower than midwidth; interarea short; delthyrium open, without elytridium. Rhizoid spines long and stout, confined to

posterior margin, posterior slopes of umbo, and ears. Ornament spines long, consisting of erect stout spines and shorter, delicate recumbent spines. Brachial valve covered by erect slender spines.

Pedicle valve interior with short median septum in young stages, generally becoming obsolete in adults; adductor muscles on median ridge or narrow platform. Diductor scars broadly flabellate.

Brachial valve with variable bilobed, stout, short-shafted cardinal process at right angles to valve in juveniles, but, with age, rotating 90° to become erect, elongated and approximately parallel to valve surface. Lateral ridges strong in the adult; cardinal process becoming trilobed or quadrilobed posteriorly with age, shaft buttressed in adult by variably developed oblique lateral plates extending from posterolateral edges of adductor field to outside base of cardinal process. Adductor field forming low platform. Inner adductor scars elongate, tear-shaped, extending anterior to outer pair; posterior pair dendritic. Brevisseptum extending from posterior edge of adductor field to maximum height just beyond midvalve. Anterior slope marked by one or more rows of thick, long endospines, posterior row having longest spines.

TYPE-SPECIES.—*Rhamnaria kingorum* Muir-Wood and Cooper (1960: 119, pls. 23, 24)

DIAGNOSIS.—Attached Aulostegoea having two series of ornament spines, one large and one small, an erect, bilobed cardinal process and a median septum in the young pedicle valve.

DISCUSSION.—Four other aulostegacean genera strongly resemble *Rhamnaria*: these are *Tschernyschewia* Stoyanow, *Bilotina* Reed, *Juresania* Fredericks, and *Ramavectus* Stehli. All have the peculiar ragged appearance given to the exterior by the large and small spine bases on the pedicle valve and the closely pitted surface of the brachial valve, *Tschernyschewia* is readily distinguished because of the enormous median septum of the pedicle valve that divides the interior into two halves. The brachial valve of *Tschernyschewia* is equally distinctive because the lobes of the cardinal process are greatly extended laterally and suggest those of *Scacchinella*.

*Bilotina*, which comes from the Permian of the Salt Range of Pakistan, is known from the exterior only. It was assigned by Reed (1944) to the Strophalosiidae but its affinities cannot be intelligently assessed until the interior of both valves is known.

Comparison of *Rhamnaria* with *Juresania* is also difficult because the interior of the European representatives of the latter are not clearly known. Some Russian authors relate *Juresania* to *Buxtonia*, which implies that the interior is that of the Buxtoniidae. American species now assigned to *Juresania* are clearly related to the Buxtoniidae because they have the characteristic buttress plates of the family in the young stages. These primary buttress plates and the cardinal process which is buxtoniid in *Juresania*, are the chief distinctions between *Juresania* (of America) and *Rhamnaria*. Comparison with *Ramavectus* is given under that genus.

**ORNAMENT.**—Stripped of its spines, the exterior pattern of the shell of both valves is distinctive. Lack of regularity in the distribution of the spine bases and pits gives the shells a disorderly appearance. The spine bases are narrowly rounded and elongated longitudinally. In places several of these are in line and give the shell a costellate appearance. These lines, however, are generally broken by fairly deep pits or shallower dimples. Commonly a dimple is surrounded by spine bases. Most of the spine bases bear long, slender spines that tend to lie parallel to the valve surface. Many of them actually lie on the valve surface but most of them extend outward at a low angle. Scattered among these slender spines appear, apparently at random, stout, long, spines that extend from the surface at an angle varying from  $30^{\circ}$  to  $90^{\circ}$ . Some of these spines arise from bases, but many appear to come from the shell surface without swollen bases.

The pits and spine bases of the brachial valve are smaller than those of the pedicle valve. The irregular ridges separating the pits are somewhat angulated. The spines tend to rise from the shell at an angle parallel to the trail. Therefore the spines in the visceral disc region are attached at a high angle but those on the trail lie nearly parallel to the trail surface. The brachial spines are very slender, almost hairlike, and are shorter than the delicate spines of the pedicle valve. A small percentage of spines on the trail and just inside the valve margin extend at a high angle to the trail surface and overhang the visceral region.

The anchor or rhizoid spines are confined to the posterior and posterolateral shell parts. The *Rhamnaria* spat is a flat expansion on some surface of sizeable dimension. As growth proceeds, spines

are sent out anteriorly and laterally to anchor the expanding shell. As vertical growth commences spines are sent out on the anterior side which extends from the shell edge directly at right angles to the surface of attachment. With continued growth in a vertical direction spines are more concentrated in the lateral regions and few are sent out on the anterior side. These anterior spines are on the umbonal slope in the adult shell and the lateral spines are those of the posterior margin and ears. In adult shells no anchor spines are sent out from the umbonal region but many are added as the shell grows laterally. It is likely, however, that some of the larger ornament spines of the umbonal region would have become rhizoid if they had made contact at their tip with a solid base.

The rhizoid spines of *Rhamnaria* are like those of other genera in their behavior. They continue to grow for a considerable distance after making contact with the anchoring surface. Consequently, some of these spines, especially the later ones on the ears, may equal or exceed the length of the valve. The shape of the umbonal region is dependent on the nature of the surface of attachment. Shells that are fortunate in establishing themselves on a flat, or nearly level surface usually have a broad cicatrix of attachment. Some specimens start life in a more precarious situation such as on a cylindrical crinoid stem. In these the cicatrix may be concave and elongate or may be a mere point. Then the attachment spines form a clasping ring around the stem. This ring may be preserved after the crinoid stem crumbles into its component segments.

The development of the interarea is spasmodic and unpredictable. Some large specimens have only a vestigial interarea, whereas others are well provided with this structure. Small specimens may have long interareas, while others have scarcely any development of the structure. The flatter specimens usually have the interarea fairly strongly developed, but the reverse is true of the strong convex ones. We have been unable to detect any pattern in the development in this structure.

Typically the interarea is narrower than the valve width at the posterior margin or between the ears. Commonly, it is longest near midvalve and may taper rapidly to disappearance on the posterior margin without reaching the ears. More rarely the interarea forms a flattened part of the ears. *Rhamnaria*, like all other attached productids, is

subject to great distortion. Specimens abbreviated laterally may have exceptionally developed interareas, such as that figured by Muir-Wood and Cooper (1960, pl. 24: fig. 7) but in other specimens the structure is scarcely noticeable.

The "delthyrium" is as variable as the interarea in which it is located. A few specimens show the classic type of delthyrium—that of a broad delta shape. In older shells this may be narrowed or widened, depending on conditions of attachment and growth. In some the delthyrium may have become reduced to a rounded indentation of slight depth in the interarea.

A few unusually developed specimens show the interarea as a flat plate anterior to the beak without a delthyrium or with only a slight posterior median wave in the interarea. In these the delthyrium has been covered, or rather, filled by a deposition of shell flush with the interarea surface, thus forming a flat elytridium. In some large specimens having a short interarea the broad delthyrium is partially plugged by a concave callosity under which the cardinal process slides.

**INTERIOR OF THE PEDICLE VALVE.**—The interior of the pedicle valve is structurally simple. It is complicated only by the median septum, best seen in the young, and by the variably developed adductor platform.

The median septum is best seen in the smaller individuals. It is well exhibited in specimens up to 25 mm in length but above that size it is less distinct and more difficult to see because of the great curvature of the umbo. In specimens less than 10 mm in length the septum occupies from one-quarter to one-third the valve length. Generally it is thickest and highest at the posterior end, where it is welded to the under surface of the flat palintrope. If the interarea is well developed and fairly long, it is usually slightly notched at the septum. It is also common for the interarea to exhibit a slight swelling medially at its contact with the septum. Development of an elytridium starts from such a point, if the palintrope and delthyrium continue to grow. In specimens larger than 10 mm the median septum is clearly visible, usually as a threadlike ridge on the floor, thickening to a substantial ridge posteriorly. In the larger specimens a septum is usually not clearly visible, and it is nearly impossible to see under the umbo where the thickened end may be.

The adductor scar is elongate, with the posterior elements obscurely dendritic. The anterior scars are elongated and usually somewhat swollen. In extreme cases they make elongate swellings on each side of the threadlike septum, and in rare examples form an elongate platform. Generally, however, in the majority of specimens, young, mature, and old, the adductor field is not exaggerated and the individual scars are difficult to determine.

**INTERIOR OF THE BRACHIAL VALVE.**—The development of the cardinal process is complicated by secondary growths that become intimately welded to it, such as the lateral plates and buttress plates. The cardinal process in young *Rhamnaria* is short-shafted, widely bilobed, and attached at right angles to the valve surface. The anterior face is somewhat excavated, forming a fairly deep hollow enclosed by the cardinal process. Each lobe of the myophore is cleft by a deep groove and the lobes diverge at an angle of about 30° to 70°. In most specimens the myophore continues widely bilobed throughout life, but in some individuals the inner branches of the lobes unite to form a myophore that is trilobed on its posterior face but bilobed when viewed anteriorly.

During the growth of the shell the cardinal process rotates through an angle of about 90°, from vertical to the valve surface to a position parallel to that surface. In a specimen 10 mm long the cardinal process lies at about 45° to the inner valve surface. Only the largest specimens attain verticality.

The myophore is extremely variable and ranges from forms laterally compressed, in which no bilobation is apparent, to specimens in which the lobes are not in contact at their base. The myophores also range from narrow and slender to thick and ponderous, none of the variations being correlated with size or thickness. Many shells having the dimensions of youth are greatly thickened and have massive myophores; other specimens, having the dimensions of large adults, commonly have cardinalia in the development stages of youth. These phenomena have been observed to some degree in most other attached productids.

The cardinal process of *Rhamnaria* is not provided with the carinate lophidium that is so characteristic of the Aulostegidae. Instead the posterior surface of the shaft is broadly to somewhat narrowly rounded. This accounts for the broad and gentle curve of the delthyrium or its remnant in the palintrope of the pedicle valve.



Lateral ridges are usually not well developed in specimens shorter than 10 mm. In larger specimens, however, these ridges become thick and prominent and are welded to the lateral margins of the cardinal process. Adults have the appearance of the cardinal process being a single structure greatly extended laterally. Not only do they have secondarily thickened lateral ridges but they also develop false buttress plates. These are oblique struts that become welded to the anterolateral bases of the cardinal process where they are joined by the lateral ridges. From there they extend anterolaterally to embrace the posterolateral edges of the adductor field. These false buttress plates, which are an adult and spasmodic character, suggest the buttress plates of the Buxtoniidae, but are oblique rather than parallel and never are seen in young shells. The buttress plates are extremely variable in development, ranging from absent to strong and conspicuous. These ridges are developed in varying degree in 30 to 50 percent of the specimens.

Other features of variation exhibited in the cardinal process are rarer. Some specimens developed two prongs that grew anteriorly on the anteroventral side of the cardinal process. These suggest the similarly situated points which are a common but variable feature of *Echinosteges* and *Edriosteges*. A plane area of variable extent is developed posterior to the lateral ridges and assisted in the movement of the valves.

The adductor platform varies from scarcely visible to thick. When positively developed the posterior scars form somewhat triangular dendritic patches that lie posterolateral to the inner patches. The latter are elongate and narrow, extending anteriorly along each side of the median septum nearly to midvalve.

The median septum originates near the posterior edge of the adductor field and extends anteriorly to beyond midvalve, where it ends near the head of the trough formed by the anteromedian sulcus. The curved and often steep anterior slope in front of the visceral region is marked by one to several rows of stout endospines.

The variation of 100 brachial valves from USNM 706b and the same number from USNM 706e was examined to determine the general distribution of buttress plates in these forms. Of the specimens from USNM 706b, 22 percent had well-defined buttress plates and 20 percent had a compressed and

elongated cardinal process but this did not necessarily accompany the development of buttress plates. In 23 percent of the specimens the cardinal process retained its juvenile forked character.

Essentially the same figures were obtained from 100 valves from USNM 706e: 22 percent had well-defined buttress plates, but 19 percent had an elongated cardinal process, some of these with buttress plates and some without, and 20 percent had a juvenile forked cardinal process.

Specimens from USNM 721u had nearly all of the specimens (about 20) with buttress plates. All of these were old adults and no really young specimens were collected. Of 31 adults of *R. tenuispinosa*, new species, from USNM 702un, 48 percent had strongly developed buttress plates. *Rhamnaria sulcata*, a new species probably related to *R. kingi* (Muir-Wood and Cooper), had 35 percent of 66 adult valves with well-defined buttress plates.

*Rhamnaria kingorum* from the Appel Ranch Member are unlike their older relatives in having 54 percent of 54 adult specimens with strongly formed buttress plates. Indeed some young specimens possess these accessory plates. Furthermore, the Appel Ranch specimens all have broad cardinal processes with well-marked bilobation.

*Rhamnaria* is one of the commonest of the Glass Mountains brachiopods. It appears doubtfully in the Neal Ranch Formation. It is positively identified as the large but seldom well-preserved *R. grandis*, new species, of the Decie Ranch Member. The Cathedral Mountain Formation has yielded superb specimens, some of large size, and the genus passes on into the Road Canyon Formation where it is common.

Its most abundant occurrence is in the Word Formation, where it appears in all members. It is common in the China Tank Member, abundant in the Willis Ranch Member, abundant in the lens between the Willis Ranch and the Appel Ranch members. It is, however, uncommon in the Appel Ranch Member. The species throughout the Word seem to form a lineage.

In the Guadalupe Mountains *Rhamnaria* is fairly common in the Getaway Member of the Cherry Canyon Formation but is rare in the higher Bell Canyon and Capitan formations. The Capitan has yielded only a few specimens of a somewhat aberrant species.

*Rhamnaria eximia*, new species

PLATE 258: FIGURES 1-26

Medium size for genus, transversely elliptical; hinge wide but slightly narrower than maximum width at about midvalve; sides rounded; anterior margin nearly straight. Cicatrix small; interarea short and inconspicuous. Ornament spines scattered, clearly differentiated into two sizes, larger ones nearly erect or slightly inclined anteriorly, smaller ones delicate and recumbent. Rhizoid spines moderately stout, in row along posterior margin, few on ears and around lateral margins. Brachial valve spines delicate and of one size.

Pedicle valve strongly and evenly convex in lateral profile, broadly and highly domed in anterior profile, median region slightly concave. Umbonal region low, beak not hanging over hinge. Posterolateral slopes very steep; sulcus shallow, originating on anterior side of umbonal region but dying out or becoming faint on anterior slope; flanks swollen; anterior and lateral slopes very steep.

Brachial valve flatly to moderately concave, most concave in anterior third and in anterolateral regions. Posterolateral margins strongly rounded and flattened. Median region anterior to depressed, umbonal region marked by low median fold of variable height.

Pedicle valve interior with adductor field slightly elevated anteriorly. Brachial valve interior with short, bilobed cardinal process, lobes usually well separated. Median septum threadlike; adductor field slightly thickened.

MEASUREMENTS (in mm).—Separated valves only.

	length	brach- ial valve length	sur- face length	hinge width	maxi- mum width	height
USNM 728f						
149451a	30.8	?	51.0	36.2	40.7	16.7
(holotype)						
149451b	28.3	?	46.5	28.8	39.0	17.8
149451c	26.4	?	46.0	24.8	32.8	15.4
149451d	?	24.0	?	22.8	35.8	?
149451e	?	24.1	?	22.0	37.4	?
149451f	?	21.5	?	23.0	33.9	?

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation.

LOCALITIES.—AMNH 625, 631; USNM 728f, 728h.

DIAGNOSIS.—Coarsely spinose *Rhamnaria* with

poorly developed sulcus in the pedicle valve, stout rhizoid spines, and short bilobed cardinal process with strong buttress plates in the brachial valve.

TYPES.—Holotype: USNM 149451a. Figured paratypes: USNM 149451b-f, h. Measured paratypes: USNM 149451b-f. Unfigured paratype: USNM 149451g.

COMPARISON.—This species is completely unlike *Ramavectus diabloensis* Stehli, which occurs at the same stratigraphic level. The rhizoid spines are stouter and less numerous than those forming a brush on the ears of *R. diabloensis*. The hinge is wider, and the cardinal process of the brachial valve significantly different.

It differs from *Rhamnaria grandis*, new species, in the elliptical outline, the shallow or almost non-existent sulcus, and the generally smaller size. It differs in the same respects from *R. tenuispinosa*, new species, and in not having the fine spinosity of that Glass Mountains species. It is wider, less sulcate, and completely differently shaped from *R. kingorum* Muir-Wood and Cooper.

*Rhamnaria grandis*, new species

PLATE 217: FIGURES 18-21; PLATE 267: FIGURES 21-24

*Waagenoconcha leonardensis* R. E. King, 1931:80, pl. 19: figs. 4a-c [not figs. 2 and 3].

Large, wider than long, greatest width near midvalve; sides rounded; anterior margin broadly rounded; ears obtuse. Surface of pedicle valve marked by short, narrowly elevated spine bases; brachial valve marked by closely crowded pits and dimples. Spines not known.

Pedicle valve strongly convex in lateral profile, maximum convexity in posterior half; anterior somewhat flattened to form a long, gently convex slope; anterior profile strongly domed, sides steep, median region forming two rounded lobes with moderately deep sulcus between; beak low, protruding slightly over interarea; umbonal region moderately swollen, only slightly elevated above interareas; median region strongly swollen; umbonal and lateral slopes steep. Sulcus originating at beak, extending to anterior margin; sulcus deepening anteriorly, bounded by strongly convex flanks. Interarea short.

Brachial valve gently concave in lateral profile, maximum convexity located just posterior to

recurved anterior margin; umbo concave, but cavity altering to broadly carinate fold extending full valve length to front margin; flanks bounding fold concave, concavity increasing anteriorly. Geniculated rim short, not strongly deflected. Ears small, flattened, demarcated by low, oblique ridges.

Interior unknown except for thick lateral ridges in brachial valve and short, erect two-pronged cardinal process.

MEASUREMENTS (in mm).—From USNM 707a, specimens 149380a (holotype) and b, respectively: length 38.4, 32.3; brachial valve length 34.0, (?); surface length 58.0, 46.0; hinge width 44.0, 25.3?; midwidth 53.0, 40.9; height 23.0, 15.3; thickness 19.0, (?).

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch, Poplar Tank, Dugout Mountain, and Sullivan Peak members).

LOCALITIES.—Decie Ranch: USNM 707a, 707g, 720g. Poplar Tank: USNM 707ha, 708e. Dugout Mountain: USNM 700o, 732e. Sullivan Peak: USNM 707d, 713c, 722-1, 727a. Skinner Ranch: King 15; USNM 705a, 710r, 712p, 716p.

DIAGNOSIS.—Large deeply sulcate *Rhamnaria* with fine spine bases.

TYPES.—Holotype: USNM 149380a. Figured paratype: YPM 11613. Unfigured and measured paratype: USNM 149380b.

COMPARISONS.—This is one of the largest species occurring in the Glass Mountains and is therefore directly comparable to *Rhamnaria leonardensis* (R. E. King) and *R. tenuispinosa*, new species. Direct comparison with *R. leonardensis* is difficult because the holotype is the only known specimen and this is represented only by a longitudinal half of the pedicle valve. Despite these deficiencies it appears to be a differently proportioned species with length and width nearly equal and having a more elevated umbonal region. It is, furthermore, less deeply sulcate than *R. grandis*.

Comparison with *R. tenuispinosa* is also difficult because the spines are preserved in that species. *Rhamnaria grandis* appears to be differently marked, with more elongate and more slender spine bases and a much deeper sulcus than that of *R. tenuispinosa*.

## *Rhamnaria kingorum* Muir-Wood and Cooper

PLATE 264: FIGURES 1-29; PLATE 265: FIGURES 1-49; PLATE 266: FIGURES 1-23

*Aulosteges guadalupensis* R. E. King (not Shumard), 1931:93, pl. 25: figs. 8, 9.

*Rhamnaria kingorum* Muir-Wood and Cooper, 1960:119, pl. 23: figs. 1-14, pl. 24: figs. 1-10.

Large, subquadrate outline, width greater than length; sides gently rounded; anterior margin gently rounded to truncate. Ears nearly right or obtuse angle, rarely extended or prominent. Anterior commissure usually gently uniplicate. Ornament spines of two kinds: numerous fine, hairlike, closely following outer shell contour, and thicker, less numerous, oblique to strongly erect, much stouter, and irregularly scattered; stout spines best developed on trail. Rhizoid spines numerous, stouter than larger ornament spines, located on posterior margin, umbo and ears. Spines on brachial valve long and hairlike.

Pedicle valve strongly convex in lateral profile, maximum convexity in posterior umbonal region; anterior profile strongly domed, with steep sides and flattened, sulcate crest. Beak small and incurved, slightly overhanging interarea; umbonal region swollen, sides steep. Median region strongly swollen, divided medially by moderately deep sulcus originating just anterior to beak; sulcus extending to anterior margin, becoming lost or flattened in marginal region of old specimens. Flanks bounding sulcus swollen, flattening on long trail. Interarea short, almost obsolete in many specimens.

Brachial valve flat to moderately concave depending on age; deepest just posterior to geniculation, or about two-thirds the length from beak; umbo swollen but region around umbo nearly flat. Median fold low, originating about 5 mm anterior to beak. Trail short, deflected at angle of 20° from plane of valve.

Pedicle valve interior with adductor field elongate but seldom thickened; median septum retained into adulthood. Brachial valve interior with adductor field slightly to moderately thickened in adults; cardinal process usually large; false buttress plates present in about 30 percent of specimens. Anterior slope of trail covered by rows of large endospines.

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	maximum width	height	thickness
USNM 706b							
149388a	36.4	?	60.0	38.4	44.6	21.5	?
149388b	29.2	?	59.0	33.0	34.2	20.8	?
149389a	37.5	25.4	71.0	29.0	36.4	22.6	16.5
149389b	31.1	24.4	58.0	29.0	35.0	21.0	15.9
149389c	28.4	22.2	54.0	29.0	32.0	17.8	13.0
149389d	26.9	21.9	56.0	34.2	35.0	19.2	13.4
149389e	27.2	22.0	48.0	28.9	30.8	15.5	12.5
149389f	23.4	18.7	37.0	18.8	24.8	12.3	9.1
149389g	16.6	13.7	25.0	11.7	20.6	7.7	6.7
149389h	12.6	10.8	16.0	6.6	13.5	4.7	4.0
149389i	8.0	7.1	10.0	4.6	9.2	2.8	2.5
USNM 706e							
149393a	32.3	?	62.0	27.0	34.6	18.5	?
149393b	27.8	?	46.0	27.6	32.8	16.5	?
149393c	28.8	?	51.0	27.4	31.6	17.6	?
149393d	24.0	?	46.0	24.9	27.9	15.0	?
149393e	20.4	?	34.0	20.0	23.8	11.0	?
149393f	18.4	?	25.0	13.9	20.1	7.6	?
149393g	14.6	?	22.5	12.0	15.3	6.7	?
149393h	12.4	?	19.5	8.8	15.1	5.5	?
149393i	10.5	?	14.0	6.4	12.7	3.7	?
149393j	9.3	?	11.5	4.8	10.0	3.0	?
149393k	6.8	4.9	7.0	3.6	6.4	2.3	1.8
149393l	5.1	4.2	5.5	3.4	4.8	1.9	1.9
USNM 706							
149387a	24.6	?	44.0	31.0	32.0	15.5	?
149387b	23.7	?	40.0	22.2?	28.8	12.8	?
149387c	18.7	?	32.0	18.9	23.4	10.7	?
149387d	15.3	?	25.0	16.4	19.0	9.0	?
149387e	13.3	?	21.0	9.3	16.4	6.6	?
149387f	11.8	?	17.0	9.3	14.4	5.4	?
149387g	10.8	?	13.0	6.6	12.3	3.0	?
149387h	7.4	?	10.5	7.0	10.4	3.0	?

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank, Willis Ranch, Appel Ranch members, and lenses above the Willis Ranch Member).

LOCALITIES.—Word: USNM 737b. China Tank: USNM 703e, 706z, 713. Willis Ranch: AMNH 505, 506; USNM 706, 706e, 723t, 724u, 735c. Lenses: 706B, 732c, 737w, 741p, 742b. Appel Ranch: USNM 704, 706d, 714o, 715i, 719z, 722t, 726t, 727j.

TYPES.—Holotype: USNM 124072b. Figured paratypes: USNM 124072 g, n. Figured hypotypes: USNM 149383b, d, f-j; 149388a, b; 149389a-e; 149697; 154213a, e, h-l, s, u; 154214 a, c-i, k, l. Measured hypotypes: USNM 149387a-h; 149388a,b; 149389a-i; 149393a-l.

DIAGNOSIS.—*Rhamnaria* generally with length slightly less than the width and valves provided

with ornament spines strongly differentiated into very fine hairlike ones and stout long spines.

COMPARISON AND DISCUSSION.—*Rhamnaria kingorum* is a common and distinctive species in limestone members of the Word Formation. Distinctions between this species and others are cited under *R. rectangulata*, new species, and *R. sulcata*, new species, which are closest to it. Distinction between other species is not so difficult as dealing with the variation within the species itself. The China Tank and Willis Ranch specimens form end members of the species, those of the China Tank generally being smaller, wider and somewhat more finely spinose; they are here termed *R. kingorum delicata*, new subspecies. Those of the lower part of the Willis Ranch Member seldom attain the large



size of those of the upper part of that limestone. A progressive increase in size occurs from the China Tank above the Willis Ranch (USNM 706b), from which level specimens attain the largest size.

*Rhamnaria* from the Appel Ranch Member are rarely as large as those from the lens at USNM 706b, but tend to be more like those from the Willis Ranch Member. Others from a still higher lens, USNM 732c and 737w are very large.

*Rhamnaria kingorum* is abundant in the middle and upper parts of the Willis Ranch. The specimens are generally well-preserved and retain

many of their spines, even on the brachial valve, where these are extremely delicate.

*Rhamnaria kingorum delicata*, new subspecies

PLATE 263: FIGURES 1-49

This subspecies is wider and more finely spinose than that of typical *R. kingorum*. Specimens are generally smaller and at USNM 726r they seldom attain the maximum size seen in *R. kingorum* from the China Tank Member.

MEASUREMENTS (in mm).—*Rhamnaria kingorum delicata*, new subspecies:

	length	brachial valve length	surface length	hinge width	maximum width	height	thickness
USNM 706c							
154221a	23.5	22.3	42.5	24.7	33.2	15.9	13.4
(holotype)							
149396a	26.6	?	44.0	28.8	36.0	13.7	?
149396b	21.9	?	37.0	21.3	27.1	14.0	?
149396c	24.0	19.9	31.0	18.7	27.6	10.0	8.8
149396d	18.5	15.9	24.5	10.8	19.8	6.7	5.8
149396e	13.9	10.5	22.5	11.8	16.0	7.3	6.5
149396f	11.1	9.4	14.0?	11.0	13.8	5.4	4.3
149396g	11.0	9.3	13.0	8.8	12.1	4.0	3.8
149396h	18.3	15.7	27.5	14.1	21.7	8.7	6.4
USNM 726r							
152675a	19.6	?	34.0	16.3	24.0	11.3	?
152675b	15.6	12.8	25.0?	11.2	18.7	8.2	7.2

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation, Word Formation (and China Tank and Willis Ranch members).

LOCALITIES.—Road Canyon: USNM 716xa. Word: USNM 731m, 731p, 731u. China Tank: USNM 706c, 726r, 733q, Willis Ranch: USNM 732s.

TYPES.—Holotype: USNM 154221a. Figured paratypes: USNM 149396c, f, h-m; 149697; 154221b, d-h, j, m-o, q; 154222a, b; 154223. Unfigured paratypes: USNM 149396a, b, d, e; 154221c, i, k, l, p.

DISCUSSION.—The specimens of this subspecies are generally thick-shelled, with positively developed interior characters suggesting individuals that were arrested in growth but attained full adult characters nevertheless.

*Rhamnaria leonardensis* (R. E. King)

*Waagenoconcha leonardensis* R. E. King, 1931:80, pl. 19: figs. 3a, b [not figs. 2a, b or 4a-c].

King figured three specimens to illustrate this species and measured a fourth which must be considered in the type lot. The holotype is a geologically younger specimen than the other three which occur in the Hess Formation. The anatomical details that can be determined from the holotype indicate that it is specifically different from the others. We therefore limit the specific name to the holotype.

The holotype specimen is the poorest of the lot described because it is only a half specimen, but it shows the beak well. Most other details of the exterior must be inferred, because the specimen is the inner filling of a large pedicle valve. It must have been somewhat square in outline, because the length and width are nearly equal. The hinge is narrower than the greatest width, which is near midvalve. The beak is small and the umbo strongly curved; the umbonal slopes are steep and the anterior slope long and gentle. The sulcus originates

near the beak, is shallow at the front, widens anteriorly, and is deepest near midvalve, where geniculation occurs.

No accurate estimate of the exterior can be made, but indications suggest elongate but narrow spine bases and dimples. The only reliable interior detail is the presence of a short and delicate median septum at the beak and for 5 mm anterior to it.

**MEASUREMENTS** (in mm).—All lateral measurements of holotype based on half measure and doubled: length 43.5, surface measure 69, hinge width 36?, midwidth 46?, height 21?.

**STRATIGRAPHIC OCCURRENCE.**—Cathedral Mountain Formation (lower = *Institella* beds).

**LOCALITY.**—King locality 120 = USNM 712o.

**DIAGNOSIS.**—No definitive diagnosis possible.

**DISCUSSION.**—We feel confident of the generic assignment of this specimen to *Rhamnaria*, rather than to *Waagenoconcha*, because of the irregular nature of the exterior as indicated on the inner filling. The regular quincuncial spine arrangement of *Waagenoconcha* is definitely lacking. The clinching feature for assignment to *Rhamnaria* is the median septum in the beak. This is a feature of exceptional rarity in the Productidina and is unknown in *Waagenoconcha*.

The type specimen is too poor to make it possible to assign any specimens of Leonardian *Rhamnaria* to this species. Perhaps some individuals from Split Tank (USNM 702un), which also occur with *Institella*, belong here but it is not possible to make sure. We are, therefore, leaving the name *Rhamnaria leonardensis* with its type specimen only.

**TYPES.**—Holotype: YPM11614.

### *Rhamnaria rectangularata*, new species

PLATE 261: FIGURES 1–15

Medium size for genus, rectangular outline, considerably wider than long; hinge equal to or wider than midwidth. Sides gently rounded to nearly straight, sloping slightly medianly; anterior deeply emarginate. Anterior commissure narrowly unipli-cate. Ears flattened, prominent. Ornament consisting of sparse spines of two sizes arising from elongate bases. Smaller spines short and prone; larger spines long, curved, and oblique. Rhizoid spines of about same diameter as larger ornament spines, few on ears and posterior margin.

Pedicle valve evenly convex in lateral profile,

convexity moderate; anterior profile strongly domed and medially sulcate. Attachment scar small. Beak small; umbo gently swollen. Sulcus originating about 10 mm anterior to beak, deep and fairly wide, deepening to anterior margin, broadly V-shaped. Flanks narrowly rounded but not greatly swollen. Anterior slope short, moderately steep. Lateral slopes steep. Ears prominent and naked except for scattered rhizoid spines. Interarea nearly obsolete.

Brachial valve lateral profile nearly flat in posterior two-thirds, but abruptly deflected dorsally in anterior third. Umbonal region (for radius of 10 mm) gently concave; concavity demarcated posterolaterally by low oblique ridge defining broad, gently concave, sparsely spinose ears. Median fold broadly carinate, best defined in anterior half, forming deep emargination at front. Areas bounding fold forming most deeply concave part of valve.

Pedicle valve interior with scarcely any thickening of adductor field. Brachial valve interior with cardinal process short and widely bilobed, lobes very short; adductor field not thickened; lateral ridges attached to cardinal process, long and slender; no false buttress plates. Median septum long and slender; endospines small and numerous on anterior slopes.

**MEASUREMENTS** (in mm).—From locality USNM 703d, specimens 149409a (holotype) and b, respectively: length 25.0, 19.4; brachial valve length 20.8, 17.2; surface length 40.0, 32.0; hinge width 29.6, 22.0; midwidth 28.0, 24.0; height 12.5, 10.5; thickness 9.3, 8.0.

**STRATIGRAPHIC OCCURRENCE.**—Road Canyon Formation.

**LOCALITY.**—USNM 703d.

**DIAGNOSIS.**—*Rhamnaria* with angular outlines, rectangular form, and sparsely distributed spines.

**TYPES.**—Holotype: USNM 149409a. Figured and measured paratype: USNM 149409b.

**COMPARISONS.**—This species may be compared to *R. kingorum* Muir-Wood and Cooper and *R. sulcata*, new species. It differs from the former in its angular outline, the prominent development and angularity of the ears, less protuberant umbo, shorter interarea, more scattered spine bases and less deeply pitted valves. *Rhamnaria rectangularata* is wider than *R. sulcata*, has a deeper sulcus, and has larger and more pronounced ears than the Get-away species.

DISCUSSION.—This is a very rare species; only two specimens are known. Many hundreds of pounds of limestone from USNM 703d were dissolved to obtain these two specimens. Two other species are known from this limestone: *R. tenuispinosa*, new species, and *R. vinnula*, new species.

*Rhamnaria shumardi*, new species

PLATE 267: FIGURES 5–20

Large, length to width ratio variable, sides

rounded, anterior margin usually indented toward brachial valve; beak erect to incurved; palintrope variable, elytridium obscure, usually short; lateral extremities rounded, narrow. Pedicle valve with moderately deep, wide sulcus originating near beak; brachial valve with corresponding broadly carinate fold. Surface of pedicle valve marked by crowded, elongated spine bases. Brachial valve pitted. Interior poorly known from juveniles only but showing evidence of short median septum in pedicle valve.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	maximum width	thickness	height
USNM 738a							
149408a	38.3	27.5	53.0	19.4?	37.5	?	14.4
149408b	30.9	?	50.0	31.9?	36.0	?	12.3
149408c	29.0	25.5	41.0	22.8*	33.3	12.3	15.0
(holotype)							
149408k	21.0	18.0	25.0	13.6	27.8	7.6	9.0+

STRATIGRAPHIC OCCURRENCE.—Capitan Formation, Bell Canyon Formation (Hegler, Pinery, and Rader members)

LOCALITIES.—Hegler: AMNH 635; USNM 731. Pinery: AMNH 537; USGS 2930; USNM 733. McCombs: AMNH 401. Rader: AMNH 409; USNM 725f. Capitan: 738a.

DIAGNOSIS.—Large *Rhamnaria* with wide sulcus.

TYPES.—Holotype: USNM 149408c. Figured paratypes: USNM 149406; 149408b, k; 154212a, b. Unfigured paratypes: USNM 149408a, d–j. Measured paratypes: USNM 149408a, b, k.

COMPARISON.—It is difficult to compare specimens from the Capitan with those from the etch-residues, but in gross terms *Rhamnaria shumardi* is a much smaller species than *R. grandis*, new species, or *R. leonardensis* (R. E. King). It is about the same size as the largest of *R. kingorum*, Muir-Wood and Cooper, but is usually narrower hinged and has a deeper sulcus and stronger fold.

DISCUSSION.—This species is uncommon, and only one lot was taken from the several localities of Capitan Limestone from which we collected. The specimens are all exfoliated and thus do not reveal many significant characters.

Silicified youthful specimens of this species from

the Bell Canyon Formation (Hegler, Pinery, Rader, and McCombs members) have a small median septum in the apex. A large fragment from the Hegler Member (AMNH 635) may be referable to *Rhamnaria*. The brachial valves of the immature forms do not exhibit any brace plates anterior to the cardinal process, but the pedicle valves have a median septum.

*Rhamnaria sulcata*, new species

PLATE 262: FIGURES 2–50

Moderate size for genus, subrectangular outline, width greater than length; hinge narrower than midwidth; sides rounded; anterior moderately emarginate. Anterior commissure strongly uniplicate. Surface rough and ragged, marked by prominent, elongate, elevated spine bases surrounding deep pits; spine bases provided with spines of two sizes, smaller ones short and recumbent, larger ones longer, much stouter and more erect. Anchor spines stout, localized on ears and posterior margin.

Pedicle valve with irregular lateral profile, anterior slope long and gently convex, but posterior third narrowly rounded; anterior profile domed, but crest deeply indented by sulcus. Beak and umbo flattened by attachment in many specimens but in

others moderately swollen. Median region swollen, deeply indented by median sulcus originating at least 7 mm anterior to beak. Sulcus broadly V-shaped, prominent at anterior and bounded throughout by narrowly rounded and swollen flanks. Ears rounded, inconspicuous. Interarea curved and long for genus in most specimens. Brachial spines, short, oblique.

Brachial valve usually widely rectangular in outline, and gently concave in profile. Umbo swollen or concave; fold low but subcarinate, extending from umbo to anterior margin; fold separating two moderately concave areas just posterior to the geniculated part of valve; geniculation usually moderate, trail usually short. Ears flattened and slightly deflected in ventrally forming low oblique ridge along line of bending.

Pedicle valve interior with short median septum gradually disappearing with age; external sulcus forming interior median ridge but adductor field not thickened; apical callosity moderately developed.

Brachial valve interior with adductor field moderately thickened in old adults; anterior adductor scars prominently elongated. Cardinal process variable, with infrequent development of false buttress plates; lateral ridges usually narrow and slender; brevisseptum reduced.

MEASUREMENTS (in mm).—Thickness of specimen 149402o, 10.1; of others, unmeasurable.

	length	brach- ial valve length	sur- face length	hinge width	maxi- mum width	height
USNM 728						
149402a (holotype)	26.3	?	48.0	23.8	35.0	16.6
149402b	25.5	?	54.0?	28.6?	33.6	16.2
149402c	22.0	?	37.0	16.3	25.9	16.0
149402d	21.0	?	40.0	19.8	27.2	14.2
149402e	18.6	?	29.0	18.8	23.0	9.3
149402f	17.8	?	32.0	14.6	22.4	10.7
149402g	16.7	?	23.0	12.6	20.9	7.6
149402h	11.2	?	15.0	6.3	14.0	4.0
149402i	?	23.4	?	18.0	32.0	?
149402j	?	21.7	?	26.3	30.7	?
149402k	?	19.4	?	17.6	24.7	?
149502l	?	13.8	?	15.5	17.6	?
149402m	?	12.0	?	8.2	15.6	?
149402n	?	7.3	?	5.6	9.3	?
149402o	20.7	17.0	?	14.7?	24.3	10.0?

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member).

LOCALITIES.—AMNH 21, 496, 512, 519, 600, 652; Moore 31; USNM 728, 730, 732.

DIAGNOSIS.—Deeply sulcate *Rhamnaria* with coarse spine bases and deep, coarse pits in both valves, especially the brachial valve.

TYPES.—Holotype: USNM 149402a. Figured paratypes: USNM 149402c, e, g, h, j, p-x. Measured paratypes: USNM 149402b-o. Unfigured paratypes: USNM 149402b, d, f, i, k-o.

COMPARISONS.—Discussion of the differences between this species and *R. rectangulata*, new species, appear under that species. Although *R. sulcata* is similar to *R. kingorum* Muir-Wood and Cooper in size and general appearance, several differences are apparent. *R. sulcata* is a somewhat wider shell with a much deeper sulcus on the pedicle valve. The sulcus is variable in *R. sulcata*, some specimens having a shallower sulcus than usual, but generally *R. kingorum* is seldom as strongly sulcate as the Guadalupe Mountains species. Another important difference between the two is the stronger and more elevated spine bases of *R. sulcata* and the deeper pitting on both valves. The deeper pitting of *R. sulcata* is strikingly seen when the brachial valves are compared.

*R. sulcata* is fairly common in the Getaway Limestone in the Guadalupe Mountains, but the preservation is not as good as that of *R. kingorum* from the Glass Mountains. No specimens of *R. sulcata* were obtained that show the full length of the spines on either valve.

### *Rhamnaria tenuispinosa*, new species

PLATE 259: FIGURES 1-33; PLATE 260: FIGURES 1-28; PLATE 261: FIGURES 16-41; PLATE 262: FIGURE 1

Large, wider than long in adult, but length and width nearly equal in old specimens; hinge narrower than greatest width at midvalve; sides gently rounded; anterior margin nearly straight; ears usually obtuse, seldom well demarcated. Anterior commissure noticeably uniplicate. Ornament spines on pedicle valve of two sizes, but both slender and delicate, longer spines attaining length of more than 20 mm, but finer spines somewhat shorter. Rhizoid spines moderately thick, of variable length. Spines on brachial valve long and hairlike, marginal ones attaining length of more than 10 mm.



Pedicle valve strongly convex in lateral profile, maximum curvature in posterior region; anterior profile strongly domed, median region sulcate, sides very steep. Beak low, slightly overhanging interarea, usually flattened by cicatrix of attachment; umbonal and median regions strongly swollen; umbo-lateral slopes steep and rounded; sulcus originating near beak, shallow and widening anteriorly, deepest medially but becoming shallow on trail in old shells. Flanks bounding sulcus in median region strongly rounded and swollen, becoming less so on trail. Anterior slope or trail, long and gentle. Interarea short and inconspicuous.

Brachial valve with unequal concavity, deepest just anterior to midvalve and just posterior to ge-

niculation. Umbo small and swollen; posterior half nearly flat but medianly marked by low carinate fold extending to anterior margin; ears flattened and inconspicuous.

Pedice valve interior with vestigial median septum in young. Adductor ridge variably developed. Brachial valve interior with long slender adductor field located on median fold (formed by sulcus) and elevated anteriorly. Interior characters of brachial valve variable. Cardinal process with lobes generally tightly joined except at distal end, seldom widely bilobed. False buttress plates present in about 50 percent of specimens studied. Adductor field seldom thickened to form platform. Median septum moderately high.

#### MEASUREMENTS (in mm).—

	length	surface length	brachial valve length	hinge width	maximum width	height	thickness
USNM 702un							
149360a	40.0	67.0	32.0	35.4?	44.9	22.0	16.5
149360b	26.4	41.0	21.8	19.3	30.0	12.8	9.0
149360c	16.1	21.0	14.6	12.8	18.2	6.0	5.0
149360d	13.4	18.0?	10.2	12.2	14.4	4.7	3.9
149360e	26.7	?	23.0	21.7	33.6	11.0?	8.2
149360f	23.3	28.0	20.2	23.7?	28.4	10.7	8.8
149360g	24.3	32.0	20.0	22.7	30.9	12.0	9.6
USNM 702c							
149359a	31.7	54.0	27.8	25.0	45.2	17.3	15.7
(holotype)							
149359b	30.9	54.5	?	18.0	37.6	17.0	?
149359c	23.7	33.0	21.0	18.0	28.7	11.0	9.3
149359d	16.6	18.0	14.3	6.8	20.3	5.6	4.8
USNM 702a							
149357a	27.7	45.0	25.5	26.8	35.2	14.0	12.3
149357b	33.0	48.0	?	?	44.0	15.4	?

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation, Road Canyon Formation.

LOCALITIES.—Cathedral Mountain: AMNH 500, 500A, 500L, 504; USNM 700-l, 702, 702a, 702b, 702un, 703a<sup>1</sup>, 703b, 703bs, 711q, 712o, 714w, 717e, 721f, 721u, 726u, 726y, 732u, 733m, 735b. Road Canyon: AMNH 503, 507; USNM 702c, 703, 703a, 703c, 703d, 707e, 709c, 719x, 720d, 721j, 721r, 721t, 721x, 721y, 721z, 723x, 724b, 724j, 726d, 726e, 726o, 726z, 732i, 732j, 736x.

DIAGNOSIS.—Large *Rhamnaria* with numerous spines, but the spines, although of two sizes, are not strongly differentiated.

TYPES.—Holotype: USNM 149359a. Figured paratypes: USNM 149356; 149357a, b; 149360c, g, h;

149373a-g; 154215a-f, h-j; 154215a-c, f-i; 154217a-e; 154218a, b; 154219b; 154220; 154531. Unfigured paratypes: USNM 149360a, b, d, e; 154215g; 154216d, e; 154219a.

COMPARISON.—The generally densely crowded and subequal spines of this species distinguish it from species of *Rhamnaria* occurring in the Word Formation. More direct comparison is therefore best made with *R. grandis*, new species, which is, however, more deeply sulcate and has somewhat more scattered spine bases.

*Rhamnaria tenuispinosa*, as represented by USNM specimens, is highly variable. Complete understanding of it is hampered by lack of a sufficient number of adult or old specimens. The genus

is not rare, but large adults are seldom taken in one piece or in good condition. However, a number of choice young adults appear fully adorned with their spines.

*Rhamnaria vinnula*, new species

PLATE 351: FIGURES 19-28; PLATE 362: FIGURES 1-28

Small to medium for genus, wider than long, transversely elliptical in outline; sides narrowly rounded; anterior margin broadly rounded to nearly straight and usually slightly indented medially. Interarea short, nearly obsolete in many specimens; delthyrium nearly obsolete. Both valves provided with numerous slender ornament spines, those of pedicle valve well differentiated into two sizes, larger ones fairly stout but smaller ones very slender. Rhizoid spines strong but not abundant on ears and in row along posterior margin, also scattered over entire valve surface. Spine bases short, narrow, crowded, irregularly arranged, forming elongate pits on pedicle valve. Brachial valve finely but irregularly pitted.

Pedicle valve moderately convex in lateral pro-

file, fairly strongly domed in anterior profile, median region slightly concave. Beak usually flattened by small cicatrix; umbonal region moderately swollen. Sulcus variable, originating on umbonal region, broad and shallow anteriorly. Anterolateral flanks moderately swollen.

Brachial valve gently but unevenly concave, most concavity anterior to midvalve; posterolateral regions strongly flattened; anteromedian region fairly strongly bent dorsally; anterolateral troughs moderately deep.

Pedicle valve interior with minute median septum in young, occasionally preserved until young adulthood, but usually resorbed before that time. Adductor region not thickened.

Brachial valve interior variably developed, usually with only slight development of accessory buttress plates; cardinal process variable, usually bilobed, lobes moderately divergent; some specimens with lobes narrowly compressed and cardinal process fairly elongated. Posterior ridge narrow; brevisseptum reduced. Brachial ridges only faintly formed; adductor scars dendritic; endospines forming fringe along anterior border.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	maximum width	hinge width	height	thickness
USNM 719x							
152677	17.8	13.6	30.0	23.0	15.8	9.2	6.6
USNM 721j							
152680a	14.4	13.0	23.0	19.6	10.6?	8.5	5.5
152680b	17.0	14.5	24.5	18.4	8.6	9.2	8.0
USNM 721z							
152679a	22.3	?	34.5	26.7	19.6	10.3	?
152679b	18.3	?	28.5	25.0	21.6	8.0	?
USNM 724a							
152676	18.5	16.6	28.0	26.9	17.6	9.1	6.3
USNM 726d							
152678a	21.5	?	39.0?	26.9	20.0	12.0	?
152678b	16.7	?	32.0	24.0	18.3	11.3	?
152678c	16.8	?	28.0	21.2	16.0	9.2	?
152678d	17.5	?	31.0	20.3	17.1	9.6	?
152678e	14.8	?	25.0	21.0	14.3	8.7	?
USNM 702c							
149359a	19.1	15.4	27.0	24.5	21.1	10.6	7.5
149359b	18.2	15.2	27.0	23.9	18.8	8.1	6.8
(holotype)							
149359c	18.8	16.5	29.0	26.0	19.9	10.3	7.4
149359d	15.0	13.2	21.0	20.0	13.7	6.4	5.5

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—AMNH 507; USNM 702c, 703c, 706f, 710z, 719x, 720d, 721j, 721z, 722e, 723w, 724a, 724c, 724d, 726d, 726x., 732j.

DIAGNOSIS.—Small to medium *Rhamnaria* with elliptical outline, moderate sulcus, and thin spines of two dimensions.

TYPES.—Holotype: USNM 149359b. Figured paratypes: USNM 149359c; 152676; 152677; 152680 a, b; 153904a–e. Unfigured paratypes USNM 149359a, d. Measured paratypes: USNM 149359 a, c, d; 152676; 152677; 154678a–e; 152679a, b; 152680a, b.

COMPARISON.—This is the smallest species of *Rhamnaria*, and need be compared only to *R. kingorum* Muir-Wood and Cooper, especially to *R. kingorum delicata* from the China Tank Member of the Word Formation. It is smaller than the largest of the China Tank subspecies, has more elongated spine bases and a less prominent sulcus on the pedicle valve. The stratigraphically younger forms of *R. kingorum* and *R. sulcata*, both new species, are generally much larger and have a stronger differentiation of the size of the spines than in *R. vinnula*. This gives specimens of the higher Word a somewhat ragged appearance as opposed to the neat appearance of *R. vinnula*.

DISCUSSION.—Although a fair collection of this species is available, the specimens consist mostly of disassociated valves and of young adults. The maximum size of the species remains in question but it may approximate the smaller forms of *R. kingorum*.

#### Family TSCHERNYSCHEWIIDAE Muir-Wood and Cooper, 1960

Aberrant Aulostegacea having a high platelike median septum in the pedicle valve; cardinal process with two divergent lobes; both valves spinose.

Genus in West Texas: *Tschernyschewia* Stoyanow, 1910.

This is one of the rare discoveries in West Texas. Two large species occur in the Glass Mountains and a small one in the Sierra Diablo. Hitherto known only in Europe and Asia from Upper Permian rocks, its geographic range now extends to North America and its stratigraphic range to the Lower Permian.

#### Genus *Tschernyschewia* Stoyanow, 1910

*Tschernyschewia* Stoyanow, 1910:853; 1910b:100, 110; 1915:3, 55.—Muir-Wood and Cooper, 1960:126.—Williams et al., 1965:H461.

*Septoproductus* Frech, 1911:75, 132.

This genus is almost unique in its possession of an enormous median septum in the pedicle valve. In the type species the septum is so large that it makes a partition dividing the valves in half. In this respect, and in the presence of a forked cardinal process, *Tschernyschewia* resembles *Scacchinella* Gemmellaro. Here the resemblance ends, because *Tschernyschewia* in external appearance is more like *Juresania* Fredericks, *Waagenoconcha* Chao, or *Ramavectus* Stehli than it is like *Scacchinella*. *Tschernyschewia typica* Stoyanow, from Djulfa, Armenia, is an almost exact homeomorph of *Waagenoconcha* because the suberect spines decrease in size anteriorly to form a marginal band of small spines. Specimens from Yugoslavia (Simic, 1933), on the other hand, are more like *Juresania* and *Ramavectus* in having elongate, strong spine bases bearing the suberect spines. The brachial valves are also provided with a forest of slender spines. *Tschernyschewia*, like *Juresania* and *Ramavectus*, lived attached for at least part of its life, and has a short interarea marked medially by a narrowed posterior denoting the position of the delthyrium. A concentrically banded plug closes the delthyrium but no well-marked elytridium appears to be present.

*Tschernyschewia* marks the Upper Permian in Europe and Asia but in the United States it occurs in Lower Permian rocks (Upper Hess, Bone Spring, and Road Canyon formations). The genus is one of the great rarities in the Permian of the Glass Mountains.

TYPE-SPECIES.—*Tschernyschewia typica* Stoyanow, (1910: 853, figs. 1, 2).

#### *Tschernyschewia americana*, new species

PLATE 268: FIGURES 1–22

Small for genus, plano- to faintly concavo-convex; wider than long, subelliptical to subrectangular in outline; maximum width near midvalve; sides well rounded; anterior margin nearly straight to slightly emarginate. Anterior commissure narrowly uniplicate. Surface irregularly marked by

fairly strong, elongate spine bases bearing short, suberect spines. Rhizoid spines short and stout.

Pedicle valve strongly but unevenly convex in lateral profile; highly domed in interior profile, with slight depression medially and very steep lateral slopes. Umbonal region somewhat flattened; interarea moderately long; sulcus narrow and shallow, originating posterior to midvalve. Flanks narrowly rounded; anterior slope steep.

Brachial valve flatly concave in lateral profile, most concave in anterior third, valve there bending

at low angle in dorsal direction. Anterolateral areas concave, but not affecting margin. Median fold low, not uniformly formed, prominent and broad in some specimens, barely visible in others.

Pedicle valve interior with strongly elevated median septum, strongly rounded distally, not quite reaching to midvalve.

Brachial valve with distantly forked cardinal process, slightly curved posteriorly and extending at angle of about 45° from plane of valve. No brevi-septum observed.

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MEASUREMENTS (in mm).—*Tschernyschewia americana*, new species:

	length	brachial valve length	surface length	hinge width	maximum width	height	thickness
AMNH 591							
149434a	11.9	10.0	19.5	9.6	14.7	7.5	6.2
149434b	11.4	9.1	16.0	7.2	13.3	5.3	4.5
149434c	12.4	10.0	19.5	7.8	16.4	7.9	7.4
149434d	13.2	11.3	?	13.0	17.9	7.9	7.0
152683c	9.4	?	11.0	5.8	10.3	3.3	?
(holotype)							

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STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation.

LOCALITY.—AMNH 591.

DIAGNOSIS.—Small *Tschernyschewia* with strongly forked cardinal process, short median septum in the pedicle valve, and poorly developed fold and sulcus.

TYPES.—Holotype: USNM 152683c. Figured paratypes: USNM 152683a, b; 149434b-d. Unfigured paratypes: USNM 149434a, e-j.

COMPARISON.—This, the smallest known species of the genus, is readily distinguished from *T. inexpectans*, new species, and other species by the poorly developed fold and sulcus as well as by the small size.

DISCUSSION.—Only a few specimens are known but some were found attached to the outer surface of large neospiriferoid brachiopods, clearly indicating the living habits. These and the exterior appearance are very similar to those of *Rhamnaria*.

*Tschernyschewia inexpectans*, new species

PLATE 268: FIGURES 23-39

Medium for genus, wider than long, transversely

rectangular to elliptical; maximum width at midvalve; sides narrowly rounded; hinge narrower than midwidth; anterior margin truncated to slightly emarginate; beak small, narrowly truncated by cicatrix, umbo protruding slightly posterior to hinge. Anterior commissure strongly uniplicate. Interarea very short, almost obsolete. Ears large, obliquely truncated. Pedicle valve marked by fairly large elongated spine bases bearing short, stout, suberect ornament spines; rhizoid spines, stout and strong, marking posterior margin and extremity of ears. Brachial valve surface with spine bases and dimples, former bearing spines smaller than those of pedicle valve.

Pedicle valve moderately and narrowly convex in lateral profile; anterior profile irregular, broadly domed, with broad median shallow region, narrowly rounded extremities, and steeply plunging sides. Umbonal region somewhat narrowly swollen, slopes steep. Sulcus originating just anterior to umbo, widening and deepening anteriorly to produce long, broadly rounded tongue. Flanks very narrowly rounded, sides nearly vertical.

Brachial valve lateral profile either faintly concave or faintly convex; umbonal region concave; median region broadly carinate, beginning slightly



posterior to midvalve to produce broad, conspicuous fold meeting strong tongue of opposite valve; anterolateral areas depressed into deep troughs extending from umbonal depression to anterolateral extremities. Ears flattened, defined by low, subcarinate ridges bounding posterior sides of oblique troughs on each side of fold.

Pedicle valve interior with erect, thin, median septum forming rounded right angle distally but

attached for about a third to a half of valve length.

Brachial valve with elongated and slightly elevated adductor field; cardinal process erect, i.e., almost vertical to hinge edge, moderately long and strongly forked at angle of about 25°. Brevisseptum thin and delicate, extending anteriorly to geniculation of brachial valve fold, there abruptly truncated, but posteriorly dying out near posterior end of adductor field.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	maximum width	height	thickness
USNM 716n							
152681	26.6	22.2	?	36.6*	42.4*	14.2	11.9
(holotype)							
152682a	25.7	21.0	47.0	28.8*	37.6*	16.5	13.9
152682b	25.6	21.0	43.0	20.6	35.6*	16.4	14.1
152682c	25.5	22.8?	44.0?	17.5	32.0*?	17.0?	15.0?

STRATIGRAPHIC OCCURRENCE.—Hess Formation (Taylor Ranch Member).

LOCALITIES.—USNM 702d, 702f, 702m, 713x, 716n, 716o.

DIAGNOSIS.—Extravagantly folded *Tschernyschewia*.

TYPES.—Holotype: USNM 152681. Figured and measured paratype: USNM 152682a, b. Figured paratype: USNM 154234. Measured paratype: USNM 152682c.

COMPARISON.—No other described species is like this one in the development of a long tongue on the pedicle valve and a strong fold on the brachial valve. *Tschernyschewia typica* Stoyanow strongly resembles specimens of *Waagenoconcha abichi* (Waagen) from the Salt Range of Pakistan, which have only a gentle sulcus on the pedicle valve and a faint fold on the brachial valve (Grant, 1966b). Specimens of *Tschernyschewia* from Yugoslavia referred to *T. typica*, or made varieties of it, are smaller than the Djulfa specimens but none of them are as extravagantly folded as the Glass Mountains species.

DISCUSSION.—The small collection of this species in the USNM is the result of a prolonged and exhaustive search of all the exposures of the Taylor Ranch Member we could find. It is evident that the species is a great rarity.

#### *Tschernyschewia* species

PLATE 269: FIGURES 1–12

A species of probably huge proportions occurs in the Road Canyon Formation. Three specimens only have been recovered; two incomplete pedicle valves and a fragment of a brachial valve. The best preserved pedicle valve, only a fragment, measures 33 mm long and 40 mm wide. The length includes the entire median septum from its origin in the apex to its anterior extremity, but much of the rest of the valve is missing. The septum is a high, thin plate, 15 mm high at its most elevated part. It is damaged along its free edge but it must have risen to a still higher crest somewhat anterior to its midlength. This specimen was narrow-hinged, the half-width measuring 15 mm; the interarea was moderately long, slightly over 4 mm. The exterior is finely ornamented, more so than *T. inexpectans*, new species.

The fragmentary brachial valve preserves the cardinal process which is stout but rather short for a large shell. It is clearly adult and is strongly forked, the cleft extending from the hinge margin to the distal extremity. Rudimentary buttress plates appear on the outside of each prong of the fork.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—AMNH 507, USNM 719x.

**TYPES.**—Figured specimens: USNM 149359a-c; 152684a, b.

**DISCUSSION.**—When found complete this will probably prove to be the largest species so far discovered in the United States.

### Family SCACCHINELLIDAE Licharew, 1928

Aberrant, specialized Aulostegacea having long conical pedicle valve cemented by apex and anchored by numerous rhizoid spines; pedicle valve interior with long median septum; dorsad growth of body accompanied by deposition of abundant, coarse, irregular, internal plates; brachial valve flatly concave or convex; interior with long forked cardinal process; adductors dendritic and on platforms.

Genus in West Texas: *Scacchinella* Gemmellaro, 1891.

This genus often attains huge size and is abundant in the Decie Ranch Member of the Skinner Ranch Formation, where it forms patches or clusters. Its earliest occurrence is in the Gaptank Formation, and in this country it evidently did not survive deposition of the Skinner Ranch Formation. The one specimen known from the Cathedral Mountain Formation is an obviously reworked valve.

### Genus *Scacchinella* Gemmellaro, 1891

*Scacchinella* Gemmellaro, 1891:22; 1892:26; 1897:114.—Schellwien, 1900b:33.—Stoyanow, 1915:64.—Licharew, 1928:265.—R. E. King, 1931:91.—Stehli, 1954:333.—Muir-Wood and Cooper, 1960:129.—Sarycheva (ed.), 1960:235.—Williams et al., 1965:H461.—Rudwick and Cowen, 1968:126–132.

Large, conical, attaining length of 150 mm, width of 65 mm. Brachial valve lidlike, varying from concave to gently convex. Interarea occupying nearly full width and entire length of pedicle valve; elytridium reduced, nearly flat and narrow. Surface of pedicle valve, except for interarea, completely spinose; spines crowded, larger ones rhizoid but smaller, hairlike ornament spines present; surface of brachial valve with short, delicate ornament spines.

Pedicle valve interior with long median septum, not reaching valve floor except at apex; muscle scars unknown; cytose shell plates occupying apical region in small geologically older species but half or more of length of larger, geologically younger specimens.

Brachial valve interior with long bilobed cardinal process, one lobe fitting on each side of median septum of pedicle valve; adductor field occupying two crescent-like plates on each side of low median septum; brachial ridges forming nearly circular patch near anterolateral side of adductor area. Anterior margin thickened.

**DIAGNOSIS.**—Large, conical Productida with abundant rhizoid spines on all parts of the exterior except the interarea, with a long median septum not meeting the valve floor posteriorly in the pedicle valve, and with a long bilobed cardinal process in the brachial valve.

**TYPES-SPECIES.**—*Scacchinella variabilis* Gemmellaro (1896) 1897, see Schuchert and LeVene 1929:110.

**COMPARISONS.**—*Scacchinella* is almost unique among brachiopods in its form and internal structure. It suggests the various richthofeniids in its conical form, but is totally unlike them in external detail and in internal structure. Furthermore, the brachial valve of the richthofeniids is located well within the conical pedicle valve, with considerable shell built above it. The brachial valve of *Scacchinella* contrasts strongly in having the brachial valve forming an external lid to the cone.

*Scacchinella* is like the members of the Gemmellaroïinae in external form and in having the brachial valve capping the cone. It is entirely unlike that family in having the deltidial structures subdued and flush with the surface of the interarea. The cardinal processes of the two are also totally unlike, that of *Gemmellaroia* being massive and bladelike, whereas that of *Scacchinella* is bilobed and elongated.

*Derbyella*, from the Permian of Mongolia, in form and exterior suggests *Scacchinella*, but a lucid comparison cannot be made until details of the pedicle valve septum of *Derbyella* are made known. Grabau's (1931a) figures suggest that the septum meets the valve floor, but this is not entirely clear. Furthermore, the deltidium is described and illustrated as elevated. Grabau's (1931a, pl. 26:fig. 2b) figure suggests an aulostegid, as he indicates, rather than *Scacchinella*, to which Grabau did not allude in connection with *Derbyella*.

The cardinal process and median septum of the pedicle valve of *Tschernyschewia* remind one strongly of *Scacchinella*, but that is a small genus having a typically productid habit. Structurally,

it could be ancestral to *Scacchinella* but has been generally found in contemporaneous or younger rocks than those that yield *Scacchinella*.

**DISCUSSION.**—The structure of *Scacchinella* has been discussed by a number of authors but some points still remain to be clarified. Unfortunately, the nature of the muscle scars of the pedicle valve cannot be now settled because none of the specimens collected in the Glass Mountains or elsewhere have these preserved. We were unable to confirm the musculature of *Scacchinella* as described by Rudwick and Cowen (1968). Details of the manner of growth and life habits, however, can be explained.

The exterior of the pedicle valve is unusual and distinctive in several ways. The lidlike brachial valve varies from moderately convex to moderately concave, but the umbonal region is nearly always convex. In section the pedicle valve has a flat palintrope, with the remainder of the valve rudely cylindrical. The interarea is completely naked, but the remainder of the valve is covered by a dense mat of spines, usually delicate-appearing because of the generally large size of the specimens. These spines are all rhizoid in character and immediately cement themselves to any solid object they touch. In addition to these rhizoid spines are fine hairlike ornament spines that curve toward the posterior, or in a direction opposite to that of the rhizoid spines.

The interarea is flat and strongly striated longitudinally. A narrow, slightly elevated ridge runs its full length. This is not the pseudodeltidium (elytridium) but is the growth track of the apex of the cardinal process, a feature like that seen on some of the Meekellidae. The margin of the palintrope is marked on each side by an angular ridge. The hinge of the pedicle valve is without teeth or articulatory processes. The lateral extremities, however, are notched for the reception of the ears of the brachial valve.

The brachial valve exterior is covered by a mat of fine, short spines probably corresponding to the hairlike spines of the pedicle valve. The hinge of the brachial valve is straight like that of the pedicle valve, but is provided with a flattened area suggesting an interarea. This flattened surface is not the exterior of a palintrope but is more in the nature of a ginglymus that fits against the palintrope edge of the pedicle valve. The brachial valve has a small, often indistinct ear that fits into the notch at

each end of the pedicle-valve hinge. The ear fits against the angular ridge on the side of the pedicle-valve palintrope.

The median septum and vesicular filling in the pedicle valve are marks of this genus. The median septum is a thin plate extending from the apex to beyond the hinge but not beyond the lateral margins of the pedicle valve. Only at the apex does this septum meet the valve floor. For its entire distance from the apex it is welded to the under side of the palintrope. The free edge of the septum is narrowly rounded and, in some specimens, somewhat thickened. In section the septum has the appearance of two plates compressed together with a thin median line between them. At its junction with the palintrope the plates flare laterally and define a small triangular chamber, which may be hollow in some specimens but is solid in most of them. The free, or distal, part of the septum is somewhat expanded and bisects the angle formed by the lobes of the cardinal process. The septum, when the valves are closed, is almost in contact with the brachial valve floor and thus makes a partition dividing the posterior part of both valves into two chambers.

The distal end of the septum and its attachment to the palintrope form an articulating device. The attachment of the septum to the palintrope ends before the hinge is reached, but the free end of the septum extends beyond this point and beyond the edge of the hinge. On the hinge, just above the median septum, is a small notch. The cardinal process prongs fit on each side of the septum and are inserted in the notch under the palintrope edge, the free end of the septum making the fit tight and laterally immovable.

Considerable variation occurs at this place of articulation. In some, the anterior side of the cardinal process prongs extend dorsally as two vertical plates into the valley between the prongs, forming a narrow slot into which the septum fits. In many specimens a small plate covering the angle of junction between the plates is formed to perfect this articulating joint. This small plate occupies the space between the palintrope and the posterior free edge of the septum at its junction with the palintrope. Thus, what appears to be a smooth hinge in both valves becomes a fairly rigid union because of the notch at the ears and the articulation of the cardinal process prongs with the posterior edge of the septum.

The apical parts of most specimens of *Scacchinella* are strengthened by irregular partitions or blisters. In some species these are poorly developed but in the gigantic forms from the Glass Mountains they occupy at least two-thirds of the pedicle valve. The largest specimen in the collection, measuring 150 mm in length, has the vesicular part 120 mm long, the remaining 30 mm having lodged the animal. The plates are very irregular but are strong and large and must have greatly strengthened these shells. In some specimens they are densely packed, with only narrow spaces between; in others they are fairly widely separated. The plates are built against the sides, floor, and median septum.

These plates make collecting a complete specimen of this genus in the Glass Mountains very difficult. When the rock is fresh, the specimens break across the vesicular area. If this region is hollow, the anterior part of the specimen is crushed. When the rock is well rotted, the *Scacchinella* crumbles throughout the vesicular part, making it rarely possible to obtain more than the nonvesicular, posterior part of the shell.

The structure of the brachial valve is unusual but, in spite of its aberrant form, shows clear relationship to the Productidina rather than the Orthotetacea. This conclusion was reached also by Muir-Wood and Cooper (1960), by the Treatise on Invertebrate Paleontology, (part H Williams et al., 1965) and by Rudwick and Cowen (1968). The most striking feature of this valve is the cardinal process, which consists of two prongs of considerable length, depending on the species, which diverge at a low angle (about  $30^\circ$ ). Each prong is slightly curved, crudely triangular in section, and cleft distally, the two inner sides of the slit being roughened. Proximally, each prong widens laterally to form a slightly concave, triangular platform having its inner edges slightly elevated. This portion of the cardinal process fits under the shelf and notch of the pedicle valve hinge, where the median septum terminates. The triangular lateral plate thus forms a sort of articulating socket.

The adductor field is unusual because the muscles are attached to two obliquely elevated plates somewhat crescentic in outline, with the concave sides facing and divided by a low median ridge. This arrangement produces a cuplike depression, on the inside of which the scars are located. Two scars appear on each side, a lower (inner) larger scar

transversely striated and an upper (outer) dendritic scar much smaller than the other. The adductor plates may be buried deeply in adventitious shell because this region in *Scacchinella* is an area of excessive shell deposit.

The median septum of the brachial valve in all species observed is low; it occupies the middle of the depression between the adductor ridges and extends anteriorly to about midvalve. Posteriorly it dies out in the trough between the adductor ridges anterior to the proximal attachment of the cardinal process prongs.

Tight junction of the brachial valve with the pedicle valve is facilitated in old specimens by the formation of a thickened rim which fits inside the anterior edge of the pedicle valve. In old specimens the sloping face of this ridge becomes rough or fluted and helps to hold the valves tightly together. The flutings are probably caused by extensions of stout endospines (taleolae?) which line the shell inside the anterior and lateral margins.

Perhaps the one feature of the brachial valve interior of *Scacchinella* that allies it closely to the Productida is the "brachial ridges." These appear in a more posterior position and are proportionally smaller than is usual in normal productids. In *Scacchinella* they are somewhat circular or obliquely oval and are located just outside the anterior half of the adductor plates. The narrow end is nearest the anterior end of the diductors. The site of the brachial ridges is one of considerable thickening, and consequently they are frequently found on thick, outwardly or laterally sloping callosities; in one specimen they occupy their own platforms.

**ECOLOGY.**—*Scacchinella* is colonial in habit and forms bioherms and patches of moderate size. The anchor spines covering the whole surface, except the interarea, permit a large surface of attachment. Specimens have been found attached to each other by almost their full length. This makes possible intimate massing of the specimens into solid patches, or bioherms. The presence of the vesicular tissue undoubtedly helped to strengthen the shell, not only for its colonial habit but for life in fairly rough water. Many bioherms of *Scacchinella* occur in the Decie Ranch and Sullivan Peak members of the Skinner Ranch Formation among large boulders and crinoidal debris which in itself is essentially a conglomerate. Some of the crinoid stems have a diameter of 2 inches and are often packed against



or in *Scacchinella* clusters. Piling of such heavy debris indicates rough water. This is true also of the coarse conglomerates with boulders up to 5 feet in length. *Scacchinella* in these members must have lived in shallow, turbulent water.

**VARIATION OF THE EXTERIOR.**—The close crowding of individuals of this gregarious genus makes identification of species exceptionally difficult because of variation in external form. One species of *Scacchinella* will have short, stout specimens, long thin ones, straight ones, others that are bent at odd angles and forms whose interiors are accelerated or retarded in relation to their size. The young of all the species may be very similar and the adults of the small forms may resemble the young of the larger ones. The seemingly hopeless task of differentiating species under these handicaps can be surmounted by collecting abundant material. Collections of gregarious forms must be large enough to work out the average characteristics of the species. When this is done the species become clear. Brachiopods also have the advantage of having two variable valves and interiors that offer specific differences.

### *Scacchinella americana* Stehli

PLATE 272: FIGURES 7–27

*Scacchinella americana*, Stehli, 1954:334, pl. 23: figs. 15, 16, pl. 24: figs. 1–4.

Small, stout, short cones; hinge variable, usually wide sides and anterior margin strongly rounded; interarea flat but apical angle variable ( $35^{\circ}$  to  $50^{\circ}$ ). Anterior margin with gentle ventrad fold. Anchor spines stout.

Pedicle valve with lateral profile triangular, posterior side flat but anterior side gently convex; anterior profile subcircular to transversely but roundly elliptical. Apex commonly distorted, usually bluntly pointed. Beak ridges strong; sides just anterior to beak ridges gently to strongly concave, sides generally bulging, maximum width at midvalve. Interarea flat and strongly striated longitudinally.

Brachial valve in lateral profile gently convex, posteromedian region gently swollen but anterior half or third flattened to moderately concave to fit ventral fold of anterior margin. Anterior profile with median region gently humped but lateral areas gently concave or nearly flat. Posterolateral extremities with small, poorly defined ears. Ginglymus moderately developed.

Pedicle valve interior with slender, delicate median septum; development of vesicular tissue generally short, confined to apex.

Brachial valve interior with short stout cardinal process with prongs diverging at about  $40^{\circ}$ , posterior face broadly flattened. Adductor platforms steeply inclined and usually strongly excavated laterally. Brachial ridges anterolateral to anterior ends of adductor platforms, small, not oblique.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
AMNH 655							
148034	31.8	31.8	51.5	20.7	36.8	40.4	40.4
AMNH 699							
148031a	31.6	31.6	47.0?	21.7	31.0	39.3	39.3
148031b	29.5	29.5	39.0?	26.7	38.6	36.4	36.4
148031c	29.4	29.4	36.0	25.8	36.7	24.0	24.0
AMNH 625							
148030	31.4	31.4	?	26.0*	36.9	?	?

**STRATIGRAPHIC OCCURRENCE.**—Lower Bone Spring Formation.

**LOCALITIES.**—AMNH 625, 628, 655, 696, 699; USNM 725c, 728e, 728f, 728h, 746.

**DIAGNOSIS.**—Short, stout *Scacchinella* with small vesicular zone.

**TYPES.**—Lectotype: AMNH 27311/1:3. Figured paratypes: AMNH 27311/1:1, 2, 4. Unfigured paratypes: AMNH 27311/1–3. Figured hypotypes: USNM 148031a, c; 148034; 153671; 153672a, b.

**COMPARISON.**—The short, stout, conical form of the pedicle valve of this species distinguishes it from

adult forms of all other species described herein except *S. primitiva* and *S. triangulata*, both new. It differs from the former in having the height greater than the midwidth, whereas *S. primitiva* generally is wider than high. Differences between *S. americana* and *S. triangulata* are not as striking as those between them and *S. primitiva* but a number of small differences add up to a considerable distinction. The pedicle valve of *S. triangulata* is more elongated and less abruptly pointed than in *S. americana*. The brachial valve of *S. triangulata* is more elliptical than that of the Sierra Diablo species, and the sides of the pedicle valve anterior to the beak ridges are less concave. Inside the pedicle valve, *S. americana* has the greater development of vesicular tissue. In the brachial valve, the adductor platforms of *S. triangulata* are neither elevated nor laterally excavated.

DISCUSSION.—*Scacchinella americana* has not yet been found in abundance. It is fairly common in the Baylor Mountains, but few good specimens have been taken. In the lower Bone Spring Formation of the Sierra Diablo it appears from time to time in the residues of large block acidizing, but the specimens are generally single valves and show evidence of having been transported for considerable distance.

*Scacchinella exasperata*, new species

PLATE 271: FIGURES 14–24; PLATE 273: FIGURES 26–28

Cone high, flattened on posterior side, hinge

wide, brachial valve gently convex; sides rounded, anterior margin rounded, with marked reentrant anteriorly; in young shells maximum width at mid-valve. Surface spinose as usual for genus.

Pedicle valve generally greatly distorted, especially at apical end but triangular in profile, posterior side usually flat and anterior side gently convex; anterior profile forming posteriorly flattened cylinder. Apical angle about 38°. Hinge about two-thirds of midwidth. Beak ridges not prominent; sides just anterior to beak ridges flattened to slightly concave; sides not strongly bulging. Umbo variable, usually showing evidence of attachment and generally bluntly pointed.

Brachial valve gently but unevenly convex, posterior having greater convexity and anterior half in young shells somewhat flattened and extended, meeting broad reentrant of pedicle valve. Umbonal region somewhat more convex than remainder of valve and slightly produced posterior to pedicle-valve hinge. Anterior profile gently humped medially, sides gently sloping, those of young shells slightly concave to fit against lateral edge of pedicle valve.

Pedicle valve interior with development of vesicular tissue in apex varying from no plates to filled for 15 mm. Median septum enormously thickened on dorsal side.

Brachial valve with cardinal process having widely divergent prongs (35°) and measuring 10 mm long in specimen 42 mm high. Adductor platforms thick, low, not excavated laterally. Brevisep-tum low.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 705k							
151686a	31.9	31.9	72.0	33.4	41.9	63.0	63.0
(holotype)							
151686b	29.4	29.4	51.0+	22.8	30.0	47.8?	47.8+
151686c	20.3	20.3	33.0?	14.4	22.8	29.3	29.3
151686d	22.0	22.0	26.0?	18.7	28.0	24.3?	24.3?
151686e	22.0	22.0	37.0	16.5	26.9	30.0?	30.0?
151686f	14.7	14.7	29.0	11.9	18.3	26.7?	26.7
151686g	9.6	9.6	17.0	8.7	13.1	16.5	16.5
151686h	10.0	10.0	11.5	7.7	12.6	9.6	9.6
151686i	7.9	7.9	10.5	6.7	8.8	9.0	9.0

STRATIGRAPHIC OCCURRENCE.—Lenox Hills Formation, Hueco Formation.

LOCALITIES.—Lenox Hills: USNM 705k, 705m, 705s, 707s. Hueco: AMNH 700; USNM 725a.

DIAGNOSIS.—*Scacchinella* of medium size, with short vesicular region, dorsally thickened median septum in the pedicle valve, and nonexcavated adductor platforms.

TYPES.—Holotype: USNM 151686a. Figured paratypes: USNM 151686b, c, g, j, k. Measured paratypes: USNM 151686b-i. Unfigured paratypes: USNM 151686d-f, h, i, l.

DISCUSSION.—Leonard Mountain has produced the only specimens of *S. exasperata* known. Although two of the localities are separated by several hundreds of feet elevation, the two occurrences are thought to be the same stratigraphic level, the lower one having dropped as a large block from the upper one.

The large bioherm at USNM 705k is unique in the mountains because the organic bulk of this bioherm is composed of *Scacchinella* and the large, elongated *Tropidelasma strobilum*, new species, intimately mingled. Unfortunately, no parts of this bioherm are silicified; consequently, the bioherm binders are not known, and many species could not be obtained in identifiable form.

### *Scacchinella primitiva*, new species

PLATE 270: FIGURES 1-11

Small for genus, fairly widely subconical, hinge much narrower than maximum shell width; sides and anterior margins strongly rounded. Interarea forming narrow triangle having apical angle of 27°. Surface with stout spines, their true nature cannot be observed in material at hand.

Pedicle valve variable in lateral profile but usually triangular, posterior side flat or gently concave, anterior side nearly flat or gently convex, and apical angle varying from 35° to 50°. Anterior profile subcylindrical. Apex blunt, usually showing signs of attachment. Ridges forming margin of interarea prominent, elevated slightly; posterolateral areas gently concave but anteriorly rounding into general valve convexity; sides bulging and strongly convex. Umbonal region usually distorted.

Brachial valve with oval outline; gently and fairly evenly convex in lateral profile, maximum convexity near midvalve; anterior profile gently convex, midregion gently humped, sides descending gently laterally.

Pedicle valve interior with stout median septum, short at apex but attaining length of 10 mm at mid-

valve in specimen 35 mm long. Apical region with short vesicular region, not over 4 mm long.

Brachial valve interior with cardinal process prongs slender, measuring about 6 mm long in specimen 26 mm high. Adductor platforms slender, closely spaced. Brevisseptum reaching to about midvalve. Brachial ridges small, nearly circular, midregion situated opposite anterolateral extremity of adductor platforms. Anterior margin moderately thickened.

MEASUREMENTS (in mm).—Brachial valve length of holotype 37.8; of others, unmeasurable.

	length	sur- face length	hinge width	mid- width	height	thick- ness
USNM 701g						
151701a	37.8	39.0?	16.7	37.5	24.2?	24.2+
(holotype)						
151701b	41.8	50.0?	24.0?	47.2	32.2	32.2+
151701c	32.1	40.0	16.2	35.0	28.9	28.9+
151701h	29.4	33.0?	12.6	30.0	22.8	22.8+

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation.

LOCALITIES.—USNM 700g; 716k?

DIAGNOSIS.—Low, stout, short cones with gently convex brachial valve and short vesicular region in pedicle valve.

TYPES.—Holotype: USNM 151701a. Figured paratypes: USNM 151701b, c, g, j. Measured paratypes: USNM 151701b, c, h. Unfigured paratypes: USNM 151701d-f, h.

COMPARISONS.—This species is distinctive and readily separable from other species of *Scacchinella* by external as well as internal characters. It is the only species in the Glass Mountains area in which the height is less than the midwidth. Thus, it is easily separated from *S. americana* and *S. triangulata*, both new species, which are conical forms.

Internally, *S. primitiva* is readily separable from other species because of the very slight development of vesicular tissue in the apex of the pedicle valve and the closely appressed adductor platforms in the brachial valve.

DISCUSSION.—This species is of great interest as the oldest *Scacchinella*. It comes from Pennsylvanian (Virgilian) rocks in the Marathon Basin about 3 miles east of Dugout Mountain. The specimens were taken from a small bioherm that has weathered into relief. The bioherm contains a great deal of laminated limestone, presumably algae, and

many small colonial rugose corals, *Amplexocarinia* (Ross and Ross, 1963:414). In addition to these the brachiopods *Teguliferina* and *Limbella* occur and show additional relationships to the Permian.

This species strongly resembles *Derbyella* Grabau (1931a) but the presence or absence of a median septum in the pedicle valve on the type specimens has not been demonstrated. Yanagida (1967:48, pl. 19: figs. 1–7) refers to *Derbyella* specimens very similar to *S. primitiva*. These have a median septum in the pedicle valve and Yanagida places *Derbyella* in the Scacchinellidae. *Derbyella* should probably be regarded as a synonym of *Scacchinella* unless it be separated for its more prominent elytridium and general lack of cystose shell. Yanagida's specimens are dated as Early Permian.

### *Scacchinella titan*, new species

PLATE 270: FIGURES 12–16; PLATE 272: FIGURES 1–6; PLATE 273: FIGURES 1–25; PLATE 274: FIGURES 1–6; PLATE 275: FIGURES 1–4; PLATE 276: FIGURES 1–3; PLATE 277: FIGURES 1–4; PLATE 278: FIGURES 1–19; PLATE 279: FIGURES 1–9; PLATE 280: FIGURES 1–8; PLATE 281: FIGURES 1–18; PLATE 282: FIGURES 1–19; PLATE 283: FIGURES 1–22; PLATE 284: FIGURES 16–30

*Scacchinella gigantea* R. E. King (not Schellwien), 1931:91, pl. 23: figs. 20–25, pl. 24: figs. 1–5, pl. 25: figs. 16–18.

*Scacchinella americana* Muir-Wood and Cooper (not Stehli), 1960:119, pl. 26: figs. 1–9, pl. 31: fig. 26.

Huge, variable, height about  $2\frac{1}{2}$  times length; outline elongate, gently tapering, conical. Brachial valve of adults regularly convex. Sides rounded; anterior margin with ventral fold in young but fairly regular in adults. Hinge wide; interarea broad. Ornament as for genus.

Pedicle valve in lateral profile forming long wedge with dorsal side flat and anterior side gently convex; anterior profile elliptical to nearly circular. Beak ridges strong; flanks just anterior to beak ridges varying from concave to flattened slightly. Sides rounded but not bulging. Interarea strongly striated. Apex of adults bluntly pointed.

Brachial valve in young flatly convex in profile, posterior half gently convex but anterior half gently concave or flattened to fit into ventrad fold of anterior commissure of pedicle valve. Anterior profile of young nearly flat. Brachial valve of adults in lateral profile moderately and evenly convex; anterior profile broadly and gently convex. Valve thick-shelled and with broad ginglymus.

Pedicle valve interior with stout median septum strongly thickened proximally along attachment with palintrope. Vesicular tissue occupying about four-fifths of height, cysts large, strong-walled, numerous.

Brachial valve with long stout cardinal process, prongs diverging at  $38^\circ$ ; adductor platforms strongly elevated, laterally excavated or enormously thickened. Brachial ridges small, subcircular, located opposite lower half of adductor platform.

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch, Poplar Tank, and Sullivan Peak members), Hess Formation (Taylor Ranch Member), Cibolo Formation (top of Transition and Breccia Zones of Udden).

LOCALITIES.—Skinner Ranch: AMNH 520; USNM 709z, 715n, 716q, 724q, 733r. Skinner Ranch (top): USNM 714z, 715f, 722o. Skinner Ranch (base): USNM 705a, 705b, 705–l, 707w, 709u, 709v, 711i, 711p, 712n, 714e, 714p, 714q, 715v, 716p, 716t, 719y, 720e, 720g, 724p, 726h, 726j. Decie Ranch: USNM 707a, 707v, 707z, 708q, 714t, 715a, 715c, 733h. Poplar Tank: USNM 708e, 710x. Sullivan Peak: USNM 707, 707b, 707t, 707x, 713c, 713i, 715h, 715j, 715m, 733j, 739q. Hess: USNM 742a. Taylor Ranch: USNM 702d, 742a. Cibolo: (Transition) AMNH 703; USNM 738n. Cibolo (Breccia): USNM 728j, 728k, 728–l, 738c, 738r, 738s.

DIAGNOSIS.—Large thick-shelled *Scacchinella* with at least two-thirds to four-fifths of the pedicle valve filled by vesicular shell.

TYPES.—Holotype: USNM 147923a. Figured paratypes: USNM 123919a, b; 123920a, d, e, g–i; 124180; 147923b, c; 147934; 147973; 147978; 147982a–c, m; 147991a, c–e, h; 148031a, c 148034 151799a–e, k–s; 153611a–h; 153662; 153664a, b; 153665a–e; 153666; 153667; 153668a, b; 153670a, b; 153671; 153672a, b; 153673a–h, j, l. Unfigured paratypes: USNM 123920b, c, f; 147923a; 147982d–l; 147991b, f, g; 151799e–j; 153673i, k.

COMPARISONS.—The fully grown adult of this species is not to be confused with any other described species in the Glass Mountains or elsewhere. King (1931:91) identified the Glass Mountains specimens as *S. gigantea* Schellwien, a species occurring in the Trogkofel Limestone of the Karnic Alps in Austria and Yugoslavia. Schellwien's (1900b:33; pl. 4) species attaining a height of about 100 mm, is not complete at the apex. It has a length of 50 mm and a maximum width of 60 mm.



The brachial valve is comparable to that of *Scacchinella titan* but the pedicle valve does not attain the great height of the Glass Mountains species. Furthermore, the Alpine form is not provided with the great amount of vesicular shell that is so characteristic of the American species. The two appear

to be quite distinct and the American one is unique for its size and great height.

Young specimens of *S. titan* may resemble the young of any other American species so great is the variability of these sessile shells. Distinction is fairly simple, however, because the young of *S. titan*, as

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 707a							
147982a	62.5	62.5	?	50.8	64.7	166.0	166.0
147982b	57.4	57.4	145.0	50.0	62.8	150.2	150.2
147982c	42.6	42.6	150.0	38.4	54.5	151.0+	151.0+
147982d	49.8	49.8	156.0	37.0	55.4	144.6	144.6
147982e	36.9	36.9	114.0	27.9	43.4	116.7	116.7
147982f	36.5	36.5	68.0?	26.0	38.4	64.7	64.7
147982g	31.4	31.4	56.0	22.0	34.8	52.9	52.9
147982h	30.3	30.3	47.0	21.4	32.2	47.3	47.3
147982i	18.6	18.6	32.0	13.2	21.2	25.6	25.6
147982j	11.2	11.2	24.0	9.1	15.1	19.0	19.0
147982k	16.4	16.4	22.0	10.7	15.6*	15.8	15.8
147982l	6.7	6.7	11.0	6.0	9.4	7.8	7.8
147982m	62.4	62.4	?	56.0	68.8	?	?
USNM 707							
147923a	47.9	47.9	131.0	42.8	48.8	119.0	119.0
(holotype)							
147923b	39.4	39.4	130.0	35.7	37.4	124.4	124.0
152685a	39.4	39.4	91.0?	31.8	44.8	83.0?	83.0?
152685b	22.7	22.7	54.0	19.6	31.2	50.7	50.7
152685c	9.6	9.6	24.0?	10.0	15.5	18.0	18.0
152685d	6.0	6.0	8.0	4.3	7.3	6.2	5.9
USNM 708q							
147991a	33.0	33.0	86.0	27.4	36.7	65.6	65.6
147991b	24.5	24.5	40.0?	20.0	29.6	31.5	31.5
147991c	18.9	18.9	46.0?	15.9	24.6	41.4	41.4
147991d	12.8	12.8	35.0	11.8	16.9	27.0	27.0
147991e	10.6	10.6	30.0	10.3	13.3	26.6	26.6
147991f	9.3	9.3	25.0	8.5	12.0	14.3	14.3
147991g	6.0	6.0	7.5	5.3	7.8*	5.9	5.9
147991h	5.8	5.8	21.0	9.6	10.0*	20.0	20.0
AMNH 703							
151799a	26.0	26.0	42.0+	20.8	31.0	44.0+	?
151799b	28.0	28.0	45.0+	20.2	32.0*	42.8+	?
151799c	21.0?	21.0	35.0?	17.1	27.3	32.0	32.0?
151799d	18.7	18.7	48.5	16.5	25.0	37.5	37.5
151799e	19.6	19.6	30.0	14.8	22.7	25.9	25.9
151799f	14.6	14.6	53.0	11.5	17.5	22.0	Too dis- torted
151799g	10.4	10.4	29.0	8.6	13.7	16.4	16.4
151799h	13.4	13.4	12.0	9.4	15.6	13.0	13.0
151799i	5.8	5.8	7.5	3.8	6.5	3.7	3.7

well as the old ones, are greatly strengthened by vesicular shell in the pedicle valve.

DISCUSSION.—That *Scacchinella titan* must have lived in turbulent water is attested by the fact that its colonies are commonly found in coarse conglomerates in the western part of the Glass Mountains and in the Chinati Mountains. It commonly occurs in large clusters, bioherms, or patches surrounded by coarse debris. The beds in which it occurs in places have boulders up to five feet in length. These coarsest boulders appear in the western part of the Lenox Hills in the Decie Ranch and Sullivan Peak members. Toward the east the boulders gradually disappear, but the *Scacchinella* bioherms are, nevertheless, surrounded by coarse debris, especially stems of large crinoids that attain a diameter of two inches, and they are characteristic of parts of the Wolfcampian, the Decie Ranch, and Sullivan Peak members. In the western part of the Lenox Hills the largest of the scacchinellas have been found and they form large clusters in the rock. Eastward the specimens are not usually so robust where the conglomerates are finer or are replaced with crinoid and shell debris; nevertheless, a few exceptionally large specimens appear. It is possible that the great development of vesicular tissue in this species is an adaptation to the rigorous environment in which it lived.

Other parts of the shell of *Scacchinella titan* indicate adaptation to harsh conditions. The shell of the brachial valve is very thick and in some specimens the areas lateral to the adductor platforms are enormously swollen, the brachial ridges being perched on mounds or on the laterally sloping faces of thick callosities. In these shells too, the marginal region of this valve is greatly thickened, especially in the short tonguelike extension of the median anterior. On these callosities the valve is usually provided with stout, thick endospines.

This species is also abundant in the Chinati Mountains, where it may be found in the exposures along Sierra Alta Creek in masses and situations like those in the Skinner Ranch Formation of the Glass Mountains. Large biohermal masses like those of the Glass Mountains occur in the so-called Breccia Beds of Udden, and *Scacchinella* is abundant in

them. These biohermal masses are surrounded and separated by conglomerates with large boulders indicating a strenuous environment like that postulated for the bottom and top members of the Skinner Ranch Formation of the Glass Mountains. Some of the material in the Chinati exposures is silicified and yields excellent study specimens.

The Transition Beds of Udden immediately under the Breccia beds also contain a large *Scacchinella* which we identify as *S. titan*, but it occurs with Wolfcampian fusulinids.

### *Scacchinella triangulata*, new species

PLATE 271: FIGURES 1-13

Variable, attaining fairly large size, conical in outline, brachial valve varying from convex in young to resupinate in large specimens. Hinge wide; surface as usual for genus.

Pedicle valve forming stout cone with rounded sides, convex anterior and flat posterior side when seen in profile. Beak and umbo generally flattened, usually bluntly pointed. Interarea wide and triangular. Beak ridges not strongly developed; flanks just anterior to beak ridges not conspicuously flattened or excavated. Anterior region broadly rounded.

Brachial valve in young specimens gently convex in lateral profile, maximum convexity in posterior region; anterior profile of young flatly convex. Old specimens convex in median region, flattening laterally, becoming slightly reflected in dorsal direction. Anterior of old specimens becoming concave, meeting anterior broad reentrant of pedicle valve margin. Young brachial valves transversely elliptical in outline; old and large specimens subcircular.

Pedicle valve interior with stout median septum, generally considerably thickened in young but with fairly strong thickening on dorsal side at place of attachment under palintrope. Vesicular tissue not developed or only slightly formed.

Brachial valve interior with stout but short cardinal process having angle of about 35°; adductor platforms not developed; brachial ridges anteroventral to adductor field.

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702q							
151694a	25.8?	25.8?	45.0	24.1	36.4	29.0	29.0
(holotype)							
151694b	20.0	20.0	35.0	20.5	26.3?	28.5	28.5
USNM 702r							
151697a	30.0?	30.0?	50.0?	30.0	38.0?	35.0	35.0
151697b	39.7	39.7	?	33.5	46.0	?	?

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member).

LOCALITIES.—USNM 701f, 701q, 701v, 701x, 702n, 702q, 702r, 703o, 703x, 713b.

DIAGNOSIS.—Medium to large *Scacchinella* with triangular outline, wide hinge, little or no vesicular shell in the apex of the pedicle valve, and non-elevated adductor platform.

TYPES.—Holotype: USNM 151694a. Figured paratypes: USNM 151691a; 151694b; 151697a, b; 153669a, b. Measured paratypes: USNM 151697a, b. Unfigured paratypes: USNM 151691, 151697a.

COMPARISON.—This species is rare and not as well represented by specimens as the others described here. It is not as stout in outline as *S. americana* Stehli and the brachial valve is more elliptical in the adult. It does not have the greatly thickened median septum so characteristic of *S. exasperata*, new species. It is so unlike *S. primitiva*, new species, as not to require close comparison, although it is one of the earlier, or geologically older, species in the Glass Mountains. That it may have attained a size comparable to *S. titan* is shown by a single brachial valve (USNM 151697b). The concave anterior of this specimen distinguishes it from the large brachial valves of *S. titan*, which are generally fairly evenly convex in lateral profile. In *S. triangulata* younger specimens are readily distinguished by the relatively small development of vesicular tissue when compared to *S. titan*.

DISCUSSION.—*Scacchinella triangulata* is represented by an indifferent lot of specimens which come from several levels in the *Uddenites*-bearing Shale Member. The majority of the specimens appear to be juveniles and none is silicified. The species is of considerable interest as being the next oldest species, *S. primitiva*, new species, being oldest. In spite of this fact the generic characters appear to be fully

developed. Perhaps the most retarded or primitive character is the poor development of the adductor platforms as elevated plates, a feature characteristic of the younger specimens. This trait of *S. triangulata* is not shared with *S. primitiva*, which has well-developed adductor platforms.

*Scacchinella* species undetermined

PLATE 277: FIGURE 5

Only two specimens were taken from the Cathedral Mountain Formation. They are fragments showing signs of wear, and so are interpreted as reworked, not originally from the Cathedral Mountain Formation. They come from USNM 721u and 731t.

Figured specimen: USNM 153663.

## Superfamily RICHTHOFENIACEA Waagen, 1885

DIAGNOSIS.—Aberrant Productidae, specialized for dwelling in clusters, having conical form, cemented by apex of cone in youth but further anchored by rhizoid spines in adults. Brachial valve opercular, located deep within cone, having bilobed cardinal process. Aperture of cone protected by spines or coscinidium (see below). Probably derived from Aulostegacea.

DISCUSSION.—The Richthofeniacea are well developed in the Permian of West Texas. In the Glass Mountains they contribute importantly to the development of bioherms and may form small clusters or colonies independently. They are less common in the Guadalupe Mountains, where they are very rare in the reefy Capitan Limestone, but occur infrequently in the Bell Canyon Formation; there they

probably formed small clusters on the sea bottom. They have a scattered occurrence in the Cherry Canyon Formation but are common in the sponge bed near the top of the Getaway Member.

Four families are recognized in this superfamily: Prorichthofeniidae, Muir-Wood and Cooper, 1960, Hercosiidae, new family, Cyclacanthariidae, new family, and Richthofeniidae Waagen, 1885. The first family, as explained below, is questionable because of inability to recognize the type species of its single genus *Prorichthofenia*. The other three families are all structurally distinct, but converge in their evolution. The early members have protective spines on the rim of the aperture; but each family develops at least one genus with a coscinidium, and one family develops two genera with this structure. *Hercosia* typifies the family Hercosiidae which is characterized by a large bladelike median septum in the pedicle valve. *Hercosia* has protective spines on the anterior only but *Hercosestria*, with a bladelike median septum, develops a flattish coscinidium.

The Cyclacanthariidae differ from the previous family in not having a median septum; in its place is a large moundlike muscle platform. *Cyclacantharia* has a circle of spines around its aperture, but *Sestropoma* has a swollen and convex coscinidium capping its aperture. A further aberrancy is *Collumatus*, which also has a coscinidium but which has eliminated its attachment spines and lives singly, clustering only by accident.

The Richthofeniidae are characterized by a myocoelidium. *Richthofenia* has protective spines at least on the anterior side of the cone, but *Coscinarina*, which also has a myocoelidium, has a well-formed coscinidium. This is a remarkable example of parallelism in different parts of the world. The Richthofeniidae, so far as known, are wholly Old World types, being well known from Sicily, China, and Pakistan.

In discussing the origin of the Richthofeniidae, Rudwick and Cowen (1968:153) argue for derivation from the Teguliferinidae, which by virtue of occurrence in the Pennsylvanian and Lower Permian, and their richthofeniid habit, would make an ideal ancestor. The similarities are obvious, but Muir-Wood and Cooper (1960) rejected these because the growth of the cup in the two genera is unlike, and in adult form is strikingly different. Furthermore, the cardinal processes of the two are

different, that of the Teguliferinidae being elevated and protuberant reminiscent of the Strophalosiacea whereas the cardinal process of the richthofeniid is low and is often extended anteriorly into two spikelike points, as in the Aulostegacea.

The "remarkable degree of parallel evolution" which Rudwick and Cowen (1968) discount is the sort of evolution that took place continually among the brachiopods. Given the stimulus to "reef" niche occupation there is no valid reason why stocks may not develop along similar lines but still maintain their own individuality.

It is interesting to note the parallel evolution that takes place in three of the families, the Hercosiidae, Cyclacanthariidae, and Richthofeniidae, which are characterized by distinctive muscle attachment areas and each of which develops a coscinidium as an end stage in their development, although one of the families is Old World and the other two are New World families:

family and genus	muscle area	protective device	attachment spines
Cyclacanthariidae			
<i>Acritosia</i>	callosity	semicircle of spines	rhizoid
<i>Cyclacantharia</i>	callosity	full circle of spines	rhizoid
<i>Collumatus</i>	callosity	coscinidium	none
<i>Sestropoma</i>	callosity	semicircle	rhizoid
<i>Taphrosestria</i>	callosity	spines form trough	rhizoid
Hercosiidae			
<i>Hercosia</i>	median septum	semicircle of spines	rhizoid
<i>Hercosestria</i>	median septum	coscinidium	rhizoid
Richthofeniidae			
<i>Richthofenia</i>	myocoelidium	semicircle of spines	rhizoid
<i>Coscinarina</i>	myocoelidium	coscinidium	rhizoid

Rudwick (1961) proposed a "rhythmic flow" method of feeding, by which nutrient-bearing currents were swept into the body cavity by rapid opening of the dorsal valve. Snapping the valve shut was visualized as creating an outward flow, so the feeding was to be accomplished by steady, rapid opening and closing of the shell through action of the dorsal valve. This mechanism was criticised by Grant (1972) who discovered that the Productidina normally bore a complex ptycholophous lophophore. He argued that the Richthofeniacea are members of the Productidina and probably also had a functional lophophore that would make feeding



by "valve flapping" inefficient, and that postulating such an abnormal mechanism is not necessary in order to explain the morphology of the, richthofeniacean shell.

### HERCOSIIDAE, new family

Richthofeniaceans having a thin, bladelike median septum in the pedicle valve. Incipient myocoelidium in young, buried by cystose tissue in adults.

Genera: *Hercosia* Cooper and Grant, 1969; and *Hercosestria* Cooper and Grant, 1969.

*Hercosia* is the more primitive of the two genera; it has spines converging over the cup, whereas *Hercosestria* has a flattened coscinidium. *Hercosia* appears in the Skinner Ranch Formation (Decie Ranch Member) and ranges into the Road Canyon Formation. *Hercosestria* appears first in the Cathedral Mountain Formation and ranges into the Road Canyon Formation, where it is abundant in isolated patches and bioherms. It is rare in the Cathedral Mountain Formation.

#### Genus *Hercosia* Cooper and Grant, 1969

*Hercosia* Cooper and Grant, 1969:7.—Stehli and Grant, 1970: 30.

Fairly large, conical, brachial valve forming lid of deep body chamber within cone. Vestibule moderately to very deep, interior marginal wall of anterior side with long and stout nonstriated protective spines. Posterior inside wall papillose but without spines. Exterior marked by concentric wrinkles; rhizoid spines stout and numerous. Apical region and posterior side with considerable development of cystose shell. Brachial valve flat or gently concave with papillose or finely spinose surface.

Pedicle valve interior with strong aulacoterma and generally with prominent posterolateral areas. Palintrope as in *Cyclacantharia*, invisible from exterior because enclosed in outer shell layer, but visible from interior. Apex on anterior side with rounded elevation surmounted by high, bladelike septum attached by proximal end.

Brachial valve interior with strong, erect, long-shafted and cleft cardinal process; partially covered dorsally by chilidium; buttress ridge low and double; brevisseptum low; adductor scars small and dendritic. Endospines long and numerous.

TYPE-SPECIES.—*Richthofenia uddeni* Böse (1916: 43, pl. 2: figs. 1–7, 9–14, 16, pl. 3: figs. 2, 3).

DIAGNOSIS.—Like *Cyclacantharia* but with a high median septum in the apex and protective spines confined to anterior side.

COMPARISONS.—The most important distinguishing characteristic of *Hercosia* is the septum at the apex of the pedicle valve, a feature not shared by any other genus of the richthofeniids except the closely related *Hercosestria*. This is not the only feature that distinguishes this genus from others, but it is the most reliable. External differences separate it from other genera, such as the fact that *Hercosia* has protective spines only on the anterior half of the aperture. This distinguishes it from *Cyclacantharia*, in which the protective spines occur around the inside of the entire rim.

The arrangement of the protective spines of *Hercosia* is like that of *Acritosia* and the Teguliferinidae. The latter usually are squat cones that are strongly oblique, thus differing strongly from *Hercosia*. A less reliable difference between *Hercosia* and the Teguliferinidae is the flared apertural lip of the adult. Except for some individuals of *Cyclacantharia*, the lip of the cup of *Hercosia* is more flared than that of any of the other genera.

The interior and exterior details of the brachial valve of *Hercosia* are not sufficiently constant nor different enough from those of the same valve of other genera to make any useful generalization. The endospines of *Hercosia* are usually numerous and fairly long in most specimens, but the feature is not constant.

DISCUSSION.—These conical forms are very susceptible to distortion in the crowded growth of a "colony," or cluster. Specimens squeezed between two or three more robust neighbors are only able to grow vertically, and thus produce an elongated form with apex solidly filled with cystose tissue. Radical variation of the exterior necessarily means changes on the interior, all of which make specific identification of isolated individuals in isolated cases or small collections difficult. Generally the apex of *Hercosia* is somewhat elongated and the apex is well supplied with cystose shell.

Rhizoid spines are generally numerous, stout, and strong, giving firm anchorage and assisting the small apical attachment in this function. Spines appear to be evenly distributed around the anterior part of the cup. They usually are not very long and

attach to the sides of adjacent relatives, but in some isolated specimens the spines attain considerable length.

One of the most variable areas in a highly variable genus occurs around the margin of the cup. In young specimens this is generally nearly circular and fairly smooth, but in some adults the rim may end abruptly in conformity with the curve of the cone and in others it may flare into a broad flange at right angles to the side of the cone or at varying high angles. In some specimens the flange is small or incipient; in others it is very pronounced and prominent. In a few specimens, the flange, instead of flaring laterally, has continued to grow in the same direction as the lip of the cone, thus producing a long hood over the brachial valve and forming a spacious vestibule to the body chamber. Specimens of this type are indeed rare and must represent the few individuals that found exceptionally favorable positions for food and oxygen, congenial temperature, and quiet water.

Another variable feature associated with the margin of the cone is the protective spines, which vary in strength, length, and branching. These spines are set on the anterior side and just below the flange, or rim. If the latter is short or low, the spines are visible and usually protrude above the margin. However, if the flange is large and conforms to the sides of the cone, the spines may be located deep within the cone, between the body and the vestibule. The angle between the spines and a plane representing the aperture is usually about  $45^\circ$  but this is not uniform, the angle being much less in some and much higher in a few. In the former cases the spines extend directly across the aperture and may cover it almost completely, whereas in the latter the spines may not effectively cover the aperture. Many of the spines branch, often making contact with their neighbors and uniting with them. In this way a more solid mesh is created, but, in this genus, the spines seldom reach directly across the aperture of the cup. They are never attached to the posterior wall as in *Taphrosetria*. The spines in *Hercosia* form a single row and generally terminate at about midvalve. The posterior side is devoid of spines but is strongly papillose.

The form of the aperture in the young is nearly circular but in the adult it is usually more nearly elliptical. Actually it is a flattened ellipse, with the posterior side usually considerably flattened, be-

cause the hood over the hinge is usually flat or gently concave, and this affects the curve of the ellipse. Some flattening may take place also on the anterior side and then the aperture is subrectangular but with rounded sides.

The features of the interior of the pedicle valve are generally much like those of the same valve of *Richthofeniacea*, but the palintrope and median septum deserve special comment. The lateral flat or concave posterolateral areas against which the tapered brachial valve fits are extremely variable. In some specimens these areas are almost nonexistent, being represented only by a slight ridge. In others they are wide, deeply concave, and conspicuous. They offer no help in specific definition.

The interarea and pseudospondylium are usually visible inside all specimens, but generally not for their full length. The apical parts of these features are generally partly buried in adventitious shell tissue laid down in the upward growth of the animal.

A strong and thin median septum is present in the apex of the shell throughout its life. In the very young the muscle area consists of two concave plates divided by a median septum. As growth continues, the apical area is thickened by cystose material and at the same time the septum grows in a dorsal direction. The initial lateral plates are soon buried in the adventitious tissue, but the septum comes to occupy the apex and is united with the posterior wall at the apical end. The free edge of the septum is located close to the under side of the pseudodeltidium, and its posterior edge is subparallel to the pseudodeltidium but never unites with it.

In large specimens the flat, bladelike septum has a nearly straight posterior edge almost parallel to the inner surface of the pseudodeltidium, although the anterior edge is somewhat excavated proximally and rounded narrowly at its distal extremity. The deep pits at the base of the median septum probably are the sites of attachment for the diductor muscles, although no scars were seen that might prove this. The septum is thought to have been the seat of attachment of the adductor muscles, because no other place in the apex is available for them.

The brachial valve interior is like that of *Cyclacantharia* in all its essentials. The cardinal process has a long shaft that is cleft to divide the process into two parts, each supported by a buttress that forms a double ridge between the adductor scars. The myophore is trilobed in posterior view

but bilobed when seen from the ventral valve. A chilidium is present in well-preserved and unabraded specimens. It is a narrow plate arched over the proximal part of the process and usually with its sides extended laterally as thin, oblique ridges extending anteriorly nearly as far as the front end of the shaft.

The double median ridge varies from low and scarcely visible to elevated and conspicuous. Lateral ridges are fairly strong and mark the posterior margins of the valve, extending anteriorly along the neck of the valve to the point where the shoulders widen.

The adductor scars are generally poorly visible but in a few specimens they are thickened and individual scars are discernible. The inner scars are elongate and tear-shaped and the outer ones larger and rounded. The latter in some specimens show a crude dendritic pattern. The brevisseptum is very subdued and visible only in the anterior part of the shell. Frequently a large endospine is extended directly from its anterior end, thus emphasizing this structure. The endospines are long, numerous, and needlelike. They are largest in the median half of the valve and there attain a length in some individuals of slightly over 4 mm.

**GROWTH.**—The growth of *Hercosia*, like that of all its relatives, depends on the niche into which the larva settled. Specimens fortunate enough to find a hospitable location that permitted normal growth generally developed the characteristic specific form. But few specimens were this fortunate, with the result that the majority are deformed in some respect. Those that settled on the sloping face or side of an object such as a bryozoan colony early developed a curved apex in their effort to develop an erect form. Most of the cups of this genus are twisted but no definite pattern is discernible.

The smallest *Hercosia* seen consists of a nearly circular ring 2 to 3 mm in diameter. As it grows, the anterior side of the ring in early life grows faster than the posterior side to produce an oblique aperture. After 1 or 2 mm of anterior growth, rhizoid spines are sent out in all directions. Strengthening of its hold on the substrate continues throughout the growth of the animal. In the youngest spat, cystose tissue was not observed to any great extent in the walls. The posterior side at the hinge and the site of the future hood appears to consist of two

layers that ultimately widen with growth by addition of cystose shell between them. In the earliest stages the two layers are adjacent and are difficult to see.

The brachial valve in these youngest stages is flat to slightly convex and is usually strongly spinose when well preserved. The hood usually appears when the spat reached an anterior growth of 3 to 5 mm, but its development is not uniform, being retarded in some specimens but more accelerated in others. The hood may remain as a small reflected lip until the cup has reached a considerable size—up to 20 mm—before the hood begins to equalize the rim of the cup. The exact stage of appearance of the protective spines is not clear. This may be due to poor silicification but also may be because of adverse living conditions or other causes. A specimen having a surface length of 5 mm has 3 rows of small spines on the inner wall of the anterior side.

Development of the apical structures and muscle area is of interest. In the youngest specimens the median septum is not visible. In more calcified but very immature specimens the septum appears as a barely perceptible myophragm. Further calcification produces a heart-shaped structure on the valve floor with the point of the heart lying in the apex and the middle divided by a fairly strong median septum highest anteriorly. On each side of the septum the diductor scars are inserted into shallow pits. With growth this structure becomes more exaggerated, the septum becoming stronger and more elevated and the floor of the muscle area becoming also elevated to form a small platform or muscle chamber—an incipient myocoelidium. In some of the larger young specimens the heart-shaped platform protrudes conspicuously as it lengthens in a dorsal direction. Along with the growth of the platform, needed strengthening on its anterior side is accomplished by deposition of strong cysts. These finally come, in the adult, to reach the margin of the plate and make it completely sessile. In some specimens it even may be buried in the cystose shell.

The young specimens vary from wide cones to shells that are almost cylindrical. The latter usually result in adults with a long, narrow, strongly cystose apex to which R. E. King applied the name *Prorichthofenia likharewi*. The wider cones do not so greatly thicken the apex.

*Hercosia delicata*, new species

PLATE 285: FIGURES 1–38; PLATE 301: FIGURES 1, 2

Small for genus, cones low, normally straight, but apically curved in some specimens; apical angle ranging from 23° to 77°, averaging about 45°. Cross section of adult near aperture usually roundly elliptical, occasionally nearly circular; aperture with reflected and flaring margin in fully grown, well-preserved specimens; posterior flattening barely perceptible to strong; surface irregularly wrinkled; rhizoid spines slender, numerous. Protective spines slender, often distally forked, usually at high angle to attachment surface, usually not extending more than a fourth to a third distance across aperture.

Pedicle valve interior with low myocoelidium in youth but later becoming muscle mound, bisected by high, sharp median septum narrowly rounded distally, and reaching beyond midvalve in adults. Posterolateral platforms small and narrow; aulacotermia forming well-marked elevated ridge, crested slightly anteromedially. Apical cystose shell occupying anterior third. Vestibule shallow; internal spines few, scattered.

Brachial valve nearly flat, minutely and densely spinose; neck short; length about 0.7 of width; cardinal process short, low, chilidium delicate. Median ridge forming two tracks, short and low, not reaching midvalve; no brevisseptum; adductor scars faintly impressed. Endospines forming single row of long, delicate, crowded spines.

## MEASUREMENTS (in mm).—

	apical angle	length	brachial valve length	surface length	hinge width	midwidth	height	thick- ness	aperture length	aperture width	flange length
USNM 726o											
152699a	46°	25.1	?	23.0?	?	29.3	21.2	?	12.5	18.5	9.0
152699b	50°	20.5	10.9	27.0	5.2	26.0	24.3	17.8	10.9	16.5	6.7
152699c	53°	19.4	?	22.0	4.6	24.0	21.7	15.5	11.5	16.8	?
152699d	48°	18.8	?	20.0	4.6	22.8	18.0	13.0	11.0	14.2	4.6
152699e	57°	16.9	?	18.0	4.0	22.5	16.5	9.9	10.0	17.2	3.8
152699f	62°	15.3	11.4	21.0	3.8	20.7	16.7	12.3	11.9	19.3	1.5
152699g	48°	13.6	10.0	18.5	4.0	17.0	17.8	12.3	9.6	14.8	2.6
152699h	50°	15.4	?	21.0	4.0	20.5	16.2	11.0	10.6	13.1	5.5
152699i	48°	15.0	?	20.0	5.0	21.2	20.3	12.8	11.6?	19.8	?
152699j	33°	12.9	?	21.0	3.8	15.6	16.8	8.7	8.7?	14.6	3.9
152699k	42°	10.6	8.6	16.5	3.5	14.8	16.5	12.6	10.5	14.4	1.0?
152699l	38°	11.7	7.5	22.0	4.0	16.0	22.4	17.1	8.2	14.0	3.0
152699m	38°	11.4	7.8	22.0?	3.8	15.3	20.0	13.3	8.7	13.8	3.0
152699n	26°	14.1	?	36.5	4.6	17.7	37.3	30.7	11.6	16.0	3.0
152699o	23°?	11.6	?	33.0?	?	20.6	26.7	20.8	10.6	18.2	5.0
152699p	33°	11.0	7.3	21.0	3.8	14.0	15.0	13.8	8.7	13.2	?
152699q	77°	11.5	8.3	13.0	3.0	13.8	8.5	6.4	11.5	13.2	?
152699r	54°	10.5	7.9	13.0	2.8	10.5	9.8	8.2	9.0	9.8	?
152699s	35°	8.8	7.5	15.0	2.6	10.8	12.3	11.5	7.9	10.0?	?
152699t	34°	6.0	4.3	6.0	1.3	5.8	4.7	3.8	5.6	5.5	?
152699u	63°	20.6	15.0	20.0	3.0	22.4	20.0	11.0	11.5	14.3	6.4
(holotype)											

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITY.—USNM 726o.

DIAGNOSIS.—Small, delicate *Hercosia* with short, protective spines.

TYPES.—Holotype: USNM 152699u. Figured paratypes: USNM 152699d-f, n-q; 154077a-c, e-g, i-k; 154078a-c; 154106a-c. Measured paratypes:

USNM 152699a-t. Unfigured paratypes: USNM 152699a-c, g-m, r-t; 154077 d, h.

COMPARISON.—This is distinguished from *H. uddeni* (Böse) by its smaller size and delicate interior.

DISCUSSION.—This species is abundant at USNM 726o, where it makes up large clusters in bioherms and patches. Preservation is excellent and a full growth series was obtained. This has the small





STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Dugout Mountain and Sullivan Peak members), Cathedral Mountain Formation (Wedin Member), Bone Spring Formation.

LOCALITIES.—Skinner Ranch (base): USNM 720e. Dugout Mountain: USNM 732e. Sullivan Peak: USNM 707b, 718z. Cathedral Mountain: AMNH 500, 500A, 500B, 500C, 500E, 500F, 500H, 500L, 500N, 500X, 501; USNM 702, 702a, 702b, 702ent, 702-low, 702un, 703a<sup>1</sup>, 703b, 703bs, 707q,

708, 711q, 712o, 721u, 723k, 723u, 723y, 724n, 726o, 726u, 726x, 726y, 727q, 732u, 733m, 735b. Wedin Member: USNM 700-l, 700x, 714w, 717e, 723v, 727p. Bone Spring: AMNH 492, 591.

DIAGNOSIS.—Fairly large *Hercosia* with thick, often long, apex composed of cystose shell.

TYPES.—Figured hypotypes: USNM 124141b; 124142a, b; 124144; 151705k; 151706a; b, i, k, l, q; 151710b; 151713a; 151714a-d; 151715a, e, h-l; 151716; 151622a; 154036; 154072a-e; 154074a-g;

	apical angle	length	brachial valve length	surface length (ant. side)	hinge width	midwidth	height	thickness	aperture length	aperture width	flange length
USNM 702un											
151715a	66°	20.7	16.0?	31.5	7.7	26.0	20.5	15.4?	31.1	25.2	8.0
151715b	68°	21.0	14.5	30.0	6.4	26.0	24.6	14.5	26.3	34.4	6.0
151715c	65°	18.4	15.0	26.0	?	25.23	24.6	14.0	26.8	31.3	9.0
151715d	48°	20.9	16.0	45.0?	6.3	24.3	36.0	28.8?	19.9	28.0	8.0
151715e	42°	22.4	13.5	32.0	6.0	25.0	32.3	24.5	26.2	34.6	6.0
151715f	29°	16.3	14.0	41.5	5.3	16.7	36.8	29.6	17.8	20.3	2.0
151715g	24°	11.8	10.0	30.0	3.5	12.8	27.6	23.7	12.4	15.5	4.5
151715h	27°	18.2	14.3	50.0	?	21.4	41.9	?	17.6	24.7	?
151715i	48°	16.0	14.0	26.0	5.0	18.7	17.4	15.2	19.6	22.0	2.0
151715j	61°	14.6	11.5	20.0	4.5	17.8	14.2	10.4	16.0	20.8	4.6
151715k	43°	10.2	9.0	21.5	2.5?	11.0	14.0	10.0	12.0	14.6	5.0
151715l	60°	8.2	7.0	12.0	2.0	8.9	7.7	5.1	9.7	11.0	4.0
151715m	48°?	6.0	5.5	5.0	1.0	5.0	5.0	3.9	7.2	7.0	2.5
(48° av.)											
USNM 702 (low)											
151713a	72°	15.2	13.0	18.0	4.5	16.0	11.0	?	16.8	19.2	?
151713b	72°	16.9	14.0	27.0	5.3	22.7	21.7	15.7	14.4	27.8	2.0
151713c	52°	16.4	13.0?	34.0	5.6	22.0	24.1	?	18.4	26.8	3.0
151713d	58°	16.9	?	30.0?	5.0	24.0	25.0	15.7	26.8	33.7	8.0
151713e	49°	18.0	13.5	24.0	4.5	21.3	19.8	?	20.5	26.5	4.0
151713f	70°?	21.0?	16.0?	38.0?	7.5	32.0	29.0	?	38.8	49.9	11.0
151713g	42°	19.8	15.0?	30.0	6.0	23.0	26.3	18.7	23.6	29.3	6.0
151713h	41°	17.4	14.0	27.0	6.5	20.5	21.6	16.4	20.5	23.7	3.0
151713i	50°	18.7	14.0	31.0	5.0	25.4	29.4	19.4?	25.2	36.8	7.0
(56° av.)											
USNM 702b											
151710a	58°	19.8	14.5	30.0	5.3	23.2	31.2	16.6	28.7	31.2	8.5
151710b	40°	16.6	12.5	33.0	4.5	29.3	24.5	16.5	28.0	31.0	10.0
151710c	36°	16.4	12.0	38.0	5.2	21.0	33.7	25.0	18.1	23.4	5.0
151710d	38°	14.4	12.5	40.0	6.0	21.0	35.0	29.6	15.0	23.2	?
151710e	62°	18.5	13.0	28.0	5.3	18.0	18.7	12.6	20.5	25.8	3.5
151710f	62°	15.5	12.0	30.0	4.8	16.5	20.0	11.6	23.3	25.2	5.0
151710g	69°	13.8	11.5	26.0	5.0	17.0	19.8	11.0	13.3	21.4	3.5
151710h	53°	15.3	12.0	25.0	4.5	14.0	21.0	14.7	17.3	21.1	2.5
151710i	54°	10.6	9.5	13.0	2.8	9.0	9.0	6.1	12.3	12.7	3.0
151710j	19°	5.7	5.0	17.0	2.0	6.7	16.7	14.0	6.5	7.9	3.0
(49° av.)											
USNM 703b											
151718a	66°	19.2	14.0?	6.3	23.4	22.0	11.4	23.0	29.6	4.0	25.0?
151718b	66°	16.3	10.0	5.2	19.4	18.0	12.8	15.9	23.6	?	25.0?
151718c	60°	15.0	12.0?	6.0	20.0	20.5	13.5	15.7	21.8	?	26.0
151718d	100°?	17.7	13.5	4.5	20.5	12.7	7.0	20.4	25.5	?	19.0



clear evidence of a coscinidium, such as that figured by King (1931, pl. 31: fig. 5). Figures of "*P.*" *likharewi* by King (1931, pl. 29: figs. 1–3) illustrate a highly variable form, with an apical angle wider than the specimen figured in the cluster of this species on plate 28 (King, 1931). The specimens attributed to this species from Las Delicias, Coahuila and the Sierra Diablo are doubtfully assignable to *H. uddeni*.

### Genus *Hercosestria* Cooper and Grant, 1969

*Hercosestria*, Cooper and Grant, 1969:7.—Stehli and Grant, 1970:30.

Cones varying from long and tapering to low and squat; aperture wide, covered by modified protective spines forming small-meshed screen or sieve (coscinidium); vestibule usually shallow. Shell usually thick, with strongly rugose exterior ("cone-in-cone" structure). Apex strongly thickened by cystose shell; rhizoid spines numerous, stout, long.

Pedicle valve interior with strong aulacoterma, large bladeliike median septum bisecting muscle area. Cystose thickening developed at base of median septum but not forming strong mound and, on occasion, partly burying septum. Hinge as in other Richthofeniidae.

Brachial valve exterior strongly papillose to spinose; slightly convex in profile. Interior with all features subdued, cardinal process low but with chilidium; lateral ridges poorly developed; brevi-septum not developed, endospines small, not always distinct.

TYPE-SPECIES.—*Hercosestria cribrosa* Cooper and Grant (1969:7, pl. 1: figs. 1–3).

DIAGNOSIS.—Like *Hercosia* in having an apical septum but with the aperture covered by a sievelike network or grating of modified protective spines (a coscinidium).

COMPARISON.—This genus need be compared only with other coscinidium-bearing genera: *Coscinarina* Muir-Wood and Cooper and *Sestropoma* Cooper and Grant. Inasmuch as all three sieve-bearing genera belong to different subfamilies the separation is easy. The form of the cup of *Hercosestria* is different from that of *Coscinarina*, which is long, slender, and large. The chief

distinction, however, appears in the interior. *Coscinarina* has a myocoelidium in the adult, a feature completely lacking in adult *Hercosestria*, which contains only a median septum. The coscinidium of *Sestropoma* is strongly arched and has a fine mesh; that of *Hercosestria* is low and often lies below the rim of the cup. Although this distinction is readily seen, the absence of either a myocoelidium or septum in *Sestropoma* is the major distinction between that genus and the other two. *Hercosestria* culminates the branch of the Richthofeniidae that started with *Hercosia*.

### *Hercosestria cribrosa* Cooper and Grant, 1969

PLATE 289: FIGURES 1–25; PLATE 291: FIGURES 1–10; PLATE 292: FIGURES 1–44; PLATE 293: FIGURES 1–26

*Prorichthofenia uddeni* R. E. King (not Böse), 1931:100, pl. 31: figs. 3 and 5.—Rudwick (not Böse or King), 1961:450–471.

*Hercosestria cribrosa* Cooper and Grant, 1969:7, pl. 1: figs. 1–3.

Variable cones of moderate size, tapering to stout, apical angle between 20° and 107° depending on position in cluster, but averaging about 54°. Cross section at aulacoterma generally roundly elliptical. Posterior and anterior surfaces noticeably flattened, sides narrowly rounded. Aperture usually flared, successive increments of shell producing strongly rugose exterior, especially in region of vestibule (cone-in-cone structure). Protective spines modified and united to form protective coscinidium (flat or gently convex) uniting with margin of hood. Rhizoid spines slender, very numerous.

Pedicle valve interior with strong aulacoterma, often merely a succession of ridges, deepest within cup posteriorly but located just dorsal to spine bases on anterior side, thus lying obliquely across cup. Anterior side of apex noticeably thickened by cystose shell, thin bladeliike septum extending into body cavity but united with pseudodeltidium at apical end. Sockets and hinge as in other Richthofeniacea. Internal spines numerous in adults. Incipient myocoelidium in young, buried in cystose shell in adults.

Brachial valve with strongly papillose to spinose exterior, spines retained throughout life. Hinge



fairly wide, neck short, indentation shallow; shoulders broadly rounded; sides narrowly rounded and anterior margin nearly straight to gently indented.

Brachial valve interior with low and subdued

cardinal process like that of other Richthofeniidae. Lateral ridges present but low and subdued; adductor field and scars indistinct; endospines small, delicate, or aborted.

MEASUREMENTS. (in mm).—

	<i>apical</i> <i>angle</i>	<i>length</i>	<i>brachial</i> <i>valve</i> <i>length</i>	<i>brachial</i> <i>valve</i> <i>width</i>	<i>surface</i> <i>length</i>	<i>hinge</i> <i>width</i>	<i>midwidth</i>	<i>height</i>	<i>thickness</i>	<i>aperture</i> <i>length</i>	<i>aperture</i> <i>width</i>
USNM 702c											
151803a	46°	14.4	12.0	21.0	31.0	6.0	23.4	32.4	24.8	23.7	31.2
151803b	46°	16.8	10.0?	17.0	30.0	4.5	19.4	29.6	22.7	18.3	20.5
151803c	27°	14.4	10.5	15.0	28.5	6.5	15.0	29.0	23.0	15.3	19.0
151803d	38°	16.0	?	?	33.0	?	19.7	31.0	20.0?	16.9	22.5
151803e	22°	14.2	10.0	13.5	50.0	5.5?	15.2	43.6	36.6	11.6?	18.6
151803f	26°	13.3	?	?	39.0	?	13.2	31.3	?	14.0	11.0
151803g	61°	16.0	12.0	15.0	21.0	5.5	17.2	21.4	12.8	17.6	21.0
151803h	62°	16.3	?	?	27.0	?	19.9	24.0	13.6?	16.2	22.0
151803i	73°	17.4	?	?	24.0	?	18.8	23.8	?	18.1	22.8
151803j	107°	13.4	11.0?	21.0?	21.0	5.0	22.5	16.5	9.6	21.4	26.7
151803k	32°	14.4	11.0?	15.0?	24.0	?	15.3	21.0	13.6	14.6	18.7
151803l	87°	13.4	12.0	18.0	18.0	4.5	19.0	13.0	10.4	17.5	21.9
151803m	67°	15.6	13.0	16.0?	19.0	?	17.6	15.0	11.2	18.0	22.0
151803n	52°	11.5	9.2	13.5	17.0	4.0	13.4	11.0	9.8	15.0	17.8
151803o	28°	13.0	10.0	12.5	31.0	5.8	14.1	18.7	18.0	14.4	16.0
151803p	90°	13.6	11.2	15.2	16.0	3.8	18.0	11.0	9.7	16.9	23.5
151803q	19°	8.7	7.1	8.3	19.0	3.0	9.2	14.0	13.7	10.3	11.8
151803r	74°	12.0	10.0	12.0	12.0	4.5	13.6	7.3	6.5	12.6	14.6
151803s	64°	9.2	8.2	8.3	10.5	2.8	9.5	8.5	7.0	11.0	12.5
151803t	103°	11.6	9.9	10.2	14.0	3.0	11.5	5.6	4.8	13.2	15.0
151803u	68°	8.6	7.1	8.0	11.5	2.8	9.1	4.7	5.3	9.4	10.4
151803v	81°	5.4	4.8	6.5	6.0	2.5	7.3	3.9	2.6	7.1	8.4
151803w	49°	7.7	6.8	8.3	10.5	2.0	8.6	8.5	8.2	9.3	10.1
151803x	50°	4.7	4.3	4.3	7.0	1.8	5.3	4.4	3.8	5.9	6.4
151803y	20°	5.6	5.0	4.5	10.0	1.8	5.5	4.8	4.2	5.9	6.6
151803z	28°	5.0	4.0	3.9	4.5	1.5	4.9	2.5	2.1	5.6	5.6
USNM 703a											
151804	72°	23.0	?	18.0	23.0	?	25.6	19.4	10.0?	12.8	20.0
(holotype)											
151805a	62°	14.3	12.0	18.0	26.0	7.0	23.4	22.0	12.0	20.5	28.3
151805b	47°	13.2	10.5?	14.0	21.0	5.0	16.9	20.0	10.6	17.0	23.5
151805c	41°	14.5	10.0?	15.0	39.0	5.0	19.0	29.9	19.0	14.0?	21.0
151805d	40°	15.4	9.0	13.0	22.0	5.0	17.9	19.4	10.4	18.0	22.4
151805e	100°	16.0	10.0	18.5	15.0	5.3	24.8	15.8	8.1	20.0	26.4
151805f	34°	13.0	8.0?	14.0	32.0	4.3	20.5	25.7	14.0?	17.3	21.0?
151805g	30°	14.4	8.0?	14.0	27.5	4.2	17.3	23.0	14.0	18.2	25.0
151805h	22°	12.7	11.0?	13.0	37.0	4.3	14.3	31.8	26.0	19.0	20.3
151805i	70°	15.3	10.0	14.0	22.0	3.8	15.9	16.0	10.0	14.9	20.7
151805j	74°	10.6	9.0	10.0	12.0	2.8	9.6	7.3	5.5	14.2	14.5
151805k	69°	8.0	7.0	8.7	13.0	2.5	9.8	5.7	5.5	10.9	12.6
151805l	40°?	10.9	8.9	10.0	18.0	2.5	11.0	12.3	11.0	12.5	14.0
151805m	88°	8.7	7.8	9.5?	9.0	2.3	11.8	4.6	4.6	9.7	13.2
151805n	61°	7.0	6.0	7.0	9.5	1.8	7.7	7.4	3.9	8.8	11.0
151805o	45°	7.0	6.0	6.8	12.0	1.7	6.8	5.8	6.8	8.7	9.1

**STRATIGRAPHIC OCCURRENCE.**—Road Canyon Formation.

**LOCALITIES.**—AMNH 501, 503, 507; USNM 702, 702c, 703, 703a, 703c, 719x, 721o, 721s, 721t, 721y, 723x, 726f, 726z, 726za, 735w.

**DIAGNOSIS.**—*Hercosestria* of moderate size, with large apical angle with flared and dorsally rugose cups.

**TYPES.**—Holotype: USNM 151804. Figured paratypes: USNM 153199. Figured hypotypes: USNM 151802a-f; 151806a, b; 154004; 154533; 154067a-k; 154068a-y; 154070a-p; 154071; 155130a-c.

**COMPARISON.**—Only two species of this genus have been identified in the Glass Mountains, consequently comparison must be limited to species of other genera. The only richthofeniid species likely to be confused with this one is *Hercosia uddeni* (Böse). Confusion is only likely in specimens from which the coscinidium has been stripped. In these, however, examination of the posterior side will generally show traces of spines or of the net. In the growth of the hood in many specimens, the early stages of the coscinidium are covered on the exterior but a trace of them usually appears on the inside.

**DISCUSSION.**—This genus and species shows the same types of variation induced by the clustered habit as that shown by other richthofeniids, and does not need to be repeated in detail here. The apical angles, as other features, show nearly perfect gradation between extremes, and it seems clear that the variations are largely from mechanical crowding and are not genetic.

This genus is essentially a *Hercosia* with a lacy cover over the aperture rather than an anterior set of protective spines. Although the two genera are morphologically similar, details of the anatomy are sufficiently distinct, as detailed above, to make *Hercosestria* a distinctive genus. Externally, the strong rugosity of the cup in the dorsal region is a constant and distinctive character. Generally in adulthood the aperture flares outward to make a strongly reflected lip. In growing the new aperture, marginal shell was laid down inside the old, but the new one again flared. The successive development of flared apertures (cone-in-cone) creates the ragged margin of the cup. In some specimens this is exaggerated, producing successive thin and delicate marginal frills.

Some richthofeniacean genera, such as *Hercosia*, have protective spines only on the anterior side;

*Cyclacantharia* has them around the entire cup; but in both of these genera, meeting of the spines at midaperture to form a complete protective cover is unusual, although attained in *Taphrosestria*. This feature has been noted rarely, but it is more common for the spines to leave a big gap at midaperture. In *Hercosestria*, branching of the protective spines and growth from opposite directions has formed the protective net of anastomosing spines (coscinidium). The coscinidium is seldom elevated above the margin, or lip, of the aperture and is usually moderately convex, in strong contrast to *Coscinarina* Muir-Wood and Cooper of Sicily and *Sestropoma* Cooper and Grant of the Guadalupe Mountains. As noted under growth, the coscinidium is a feature of the adult.

Nothing unusual was noted about the rhizoid spines of this species, but in some specimens they appear to be more abundant than is common in these brachiopods. This is especially true of specimens from USNM 703a, which have a veritable forest of spines to anchor one small cup. This luxuriant growth offers habitation for a variety of young of other cemented brachiopods and niche dwellers.

Some variation in the growth of the apical septum can be seen inside the pedicle valve. In many of the young, especially those having a long cystose apex, the muscle region consists of two small but very deep pits divided by the median septum, thus simulating the myocoelidium of the Richthofeniidae. In specimens where deposition of cysts has not kept pace with growth of the muscle field, or in some cases of imperfect preservation, the dorsal part of the muscle area protrudes noticeably beyond the thickened muscle region and further emphasizes the similarity to the myocoelidium. In specimens where formation of cysts on the valve floor has been accelerated, the septum is seen with difficulty and may be almost completely buried. Partial obliteration of the septum also takes place on the opposite side of the valve in which the distal edge is partly buried in adventitious shell laid down on the posterior side of the apex along the pseudodeltidial region. Similar phenomena also take place in the flatter shells having large apical angles.

**GROWTH.**—This species appears to reach at least half its growth before the protective spines form. These appear as small and slender spines on the

anterior side. At this stage the posterior hood is beginning to form. The coscinidium does not become established across the cup until the hood on the posterior side is fully formed. Specimens too young to have developed protective spines are usually characterized by only a small development of the hood, and the anterior side is higher than the opposite side. The posterior side is evened in later growth by the hood, which in some specimens actually out-distances the anterior side. After the hood is fully established the spines form the network attaching the two sides.

*Hercosestria laevis*, new species

PLATE 290: FIGURES 20-42

*Prorichthofenia uddeni* R. E. King (not Böse), 1931, pl. 31: fig. 5.

Usual size for genus, longer than wide, conical,

apical angel about 65°. Cross-section at aulacotermia roundly elliptical to nearly circular; posterior surface flattened but side and anterior rounded; aperture not flared and without cone-in-cone structure; aperture usually oblique in side view; coscinidium of anastomosing spines, flattened anteriorly and slightly convex and elevated above aperture margin on posterior side. Rhizoid spines moderately abundant.

Pedicle valve interior with strong aulacotermia; median septum bladelike, almost reaching the dorsal brachial valve; vestibule shallow; cystose apical region short.

Brachial valve exterior smooth and with slight median ridge. Brachial valve interior with stout, bilobed cardinal process buttressed by paired median ridge; adductor impressions deeply inserted; median ridge threadlike; endospines short and stout forming single row.

MEASUREMENTS (in mm).—

	apical angle	length	surface length	midwidth	height	thick- ness	aperture length	aperture width
USNM 721u								
154073f	60°	13.8	24.0	13.0	22.0	12.0	17.3	20.0
154073h	67°	12.0	20.0	16.0	20.6	13.2	13.3	18.0
154073i (holotype)	65°	18.4	32.0	21.0	31.0	17.0	22.5	24.4

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITIES.—USNM 721o, 721u.

DIAGNOSIS.—*Hercosestria* with slightly flared aperture and no development of cone-in-cone structure.

TYPES.—Holotype: USNM 154073i. Figured paratypes: USNM 154073a-d, f-h, j.

COMPARISON.—Compared to *H. cribrosa* Cooper and Grant this species is readily recognized by its relatively smooth exterior with no cone-in-cone development, the modest flare to the aperture, the slightly posteriorly convex coscinidium, and the more robust brachial valve.

DISCUSSION.—This rare species has been found only in the lower part of the Cathedral Mountain Formation where it occurs with *Institella*. Other *Institella* localities have failed to produce it, except

for R. E. King's locality 120, not far north of USNM 721u.

CYCLACANTHARIIDAE, new family

Richthofeniaceans without median septum in pedicle valve.

Genera in West Texas: *Taphrosestria*, new genus; *Collumatus* Cooper and Grant, 1969; *Cyclacantharia* Cooper and Grant, 1969; *Sestropoma* Cooper and Grant, 1969.

*Taphrosestria* is a small, squat genus with cup spines forming a funnel. This genus is confined to the Road Canyon Formation. *Cyclacantharia* is the most abundant form in West Texas and is typified by having protective spines around the entire rim of the cup. It ranges from the Skinner Ranch Formation into the Capitan Formation of the Guada-

lupian Series. *Sestropoma* with a highly convex coscinidium characterizes the Bell Canyon Formation and also occurs in the Capitan Formation. *Collumatus* is an offshoot in which attachment is by sheets of shell rather than hollow spines.

### Genus *Cyclacantharia* Cooper and Grant, 1969

*Prorichthofenia* (part) R. E. King, 1931:97.—Böse, 1916:536.—Stehli, 1954:332.—Muir-Wood and Cooper, 1960:139.—Rudwick, 1961:451.

*Cyclacantharia* Cooper and Grant, 1969:7.

DISCUSSION.—The American concept of *Richthofenia* was first explained by Girty (1909:283) who based his views on an interpretation of a few specimens collected from the Guadalupe Mountains of West Texas, all of which were identified with *Crania permiana* Shumard. Although Girty's four lots of richthofeniids came from different levels in the Guadalupe Mountains and some of them came from the Glass Mountains, and each lot came from different stratigraphic horizons, they were all, nevertheless, identified with Shumard's species which was never illustrated. The specimens on which *Crania permiana* Shumard were based came from the "White limestone," now the Capitan Limestone. Girty (1909) illustrated a single specimen, a young incomplete individual which lacked the vestibule and its accessories. Girty's material was quite inadequate for an evaluation of generic characters. In spite of this he suspected that he was not dealing with *Richthofenia*.

In an exhaustive study of the richthofeniids occurring in the Glass Mountains, Böse (1916) clearly pointed out the important differences between the North American species and those of Europe and Asia.

R. E. King (1931:97) recognized the unique character of the richthofeniid-like brachiopods that are so common in the Glass Mountains. King was, however, influenced greatly in his specific determinations by the prior work and interpretations of Girty, who was the recognized American authority on this subject. Shumard's name, following Girty, was thus carried from the Guadalupe Mountains and applied to a variety of conical brachiopods. King had the advantage over Girty in having abundant specimens, including many silicified ones that yielded many details of the interior. On the basis of these King created the genus *Prorichtho-*

*fenia* following Girty and Böse, and named as type species of the genus, Shumard's *Crania permiana*, a species which never has been interpreted and the type specimens of which have been lost for many years. Understanding of *Prorichthofenia* then rests on a knowledge of *Crania permiana*, impossible to obtain. The problem is complicated further by the fact that two genera of prorichthofeniid brachiopods occur in the Capitan Limestone and its equivalents.

Upper Guadalupian rocks contain prorichthofeniids of two types: one having a ring of protective spines around the cup, and the other with the spines modified into a netlike sieve, the coscinidium, arched over the pedicle opening, suggesting *Hercosestria* Cooper and Grant (1969). Inasmuch as the identity of Shumard's species cannot be established positively and recourse to topotypes is not possible because Shumard named no type locality other than the Guadalupe Mountains, it seems best to leave King's name a *genus inquirendum*. We have created, therefore, a new name based on the superb material from the Glass Mountains that had been erroneously assigned to Shumard's species.

An effort was made to identify Shumard's species from the Capitan Limestone but this has proved impossible. The common prorichthofeniid in the Bell Canyon equivalents of the Capitan Limestone such as the Hegler, Lamar, and Radar Limestone members, all belong to the genus *Sestropoma*, which has a convex net over the aperture. Newell et al. (1953, pl 27: fig. 1) figure a specimen from the Tansill Limestone which preserves the coscinidium to perfection, indicating that this type actually appears in the limestone. On the other hand, a large collection from the Carlsbad Limestone, another facies of Capitan age, shows no trace of the coscinidium on any specimen.

In his original conception of *Prorichthofenia*, which is an unfortunate name because it may not be directly related to *Richthofenia*, King (1931) included three genera: 1, those having a high bladelike apical septum but protective spines only on the anterior side of the cup, now called *Hercosia*; 2, those having a bladelike septum and a coscinidium now called *Hercosestria*; and 3, those with a complete circle of protective spines around the cup aperture but without an apical septum, now called *Cyclacantharia*. *Prorichthofenia* from its inception has never been a clean-cut concept. It



seems best, therefore, to let it stand as unrecognized even though we have to use it as a family name.

*Cyclacantharia* is defined as follows: Large, erect cones, aperture wide, brachial valve forming lid over deep body chamber. Vestibule moderately deep. Marginal inner wall of aperture with ring of protective spines, those of anterior large and stout, those opposite usually somewhat smaller. Apex usually not strongly thickened by cystose shell. Exterior with concentric wrinkles and numerous long, stout rhizoid spines.

Pedicle valve interior with strong aulacotermia and posterolateral ridges. Palintrope prominently displayed on interior, usually not covered apically, with long narrow pseudodeltidium and flat bounding ridges, helping to articulate brachial valve. Apex variable, smooth in some species, others with rounded ridge, occasionally sharp-crested, but none with bladelike septum.

Brachial valve interior with double-shafted cardinal process, usually low and subdued; lateral ridges poorly developed; median ridge buttressing cardinal process not well developed or absent, adductor scars not thickened; endospines large, stout, generally few.

TYPE-SPECIES.—*Cyclacantharia kingorum* Cooper and Grant (1969:7, pl. 5: figs. 13–16).

DIAGNOSIS.—Large Prorichthofeniidae without a median septum and with protective spines all around the inside of the cup aperture.

COMPARISON.—Well-preserved specimens of *Cyclacantharia* are easily distinguished from all other richthofeniids, differing from Old World genera in not possessing a myocoelidium. It is distinguished from *Hercosia* and *Hercosestria* by absence of the knife-edge septum, characteristic of those genera, and in having a complete circle of protective spines around the inside of the cup. It differs from *Sestropoma*, which has a similar interior, by absence of the coscinidium.

*Acritosia* is like *Cyclacantharia* in its large size and has the interior similar, but is usually oblique and with a smaller body chamber and a larger teguliferoid cardinal process. *Acritosia*, furthermore, does not have the protective spines in a circle around the cup: they are confined to the anterior side.

DISCUSSION.—This genus has a fairly large conical cup with an apical angle commonly near 45°. It

is not as variable as the pedicle valve of *Hercosia*, and generally long narrow forms of low apical angle are uncommon. Like *Hercosia* it shares the flattened posterior side but generally the flattening in the adults is commonly not strong and the adult aperture is somewhat rounder. The cup is anchored by stout rhizoid spines, of considerable length when necessary but usually attaching to objects in close proximity. These spines appear to be as numerous on the posterior and anterior sides as on the lateral surfaces.

The protective spines on the inner side of the cup near the margin on the anterior side form a distinct band of several rows. On a specimen 25 mm in length this band is 8 mm wide and four rows of spines can be counted. On the opposite side the posterior spines have not yet formed. Usually the spines on the posterior side appear after those of the anterior side. The spines of the young are small and delicate but, as the shell grows, the spines thicken and lengthen, those of the anterior side being the longer and larger of the two sides. In large specimens they attain a length of 10 or 12 mm but one specimen with aperture of about 20 mm has the median spines 17 mm in length. In old specimens, many of the spines branch distally but they do not grow together nor do the two sets unite over the aperture. In some specimens, branching takes place near the place of origin of the spine. The larger spines are strongly striated longitudinally, the smaller ones less clearly, but all bear ridges.

The spines on the posterior side are less developed and their purpose as protective devices is not clear. In *C. kingorum* from the Glass Mountains they appear on the inner surface of the hood in a broad band of several rows, mainly graduated in size, the larger appearing nearest the margin. In this species these seldom attain the size or strength of those on the anterior side but in *C. robusta* from the Guadalupe Mountains the margin of the posterior hood bears stout spines. Some of these are directed parallel to the axis of the cone but they do not seem to have had a protective function.

The margin of the cup is commonly marked by a thin layer of cystose shell forming a band of varying width. Buried in this layer are the early formed spines, engulfed in the growth of the cup. In some the protrusion of the ends of these spines along the margin of the hood causes a serrate edge.

The apex of *Cyclacantharia* commonly is not greatly thickened by cystose shell. Usually the apex is bluntly pointed and the floor on the anterior side is not greatly thickened. Specimens exist, however, which have been crowded to such an extent that they could not grow normally. In these the apex is greatly elongated and cystose shell strongly developed. They resemble some forms of *Hercosia uddeni* (Böse).

The concave or flat lateral areas that occupy the reentrant on each side of the slot into which the neck of the brachial valve fits are well developed in this genus. These areas surmount the long and prominent rounded tracks bounding the pseudodeltidial region. The sockets on the inside of the distal extremity of these tracks are deep and are located opposite a slight elevation forming the termination of two flat plates bounding the posterolateral areas and the groove formed by the pseudodeltidium. These flat longitudinal tracks represent the growth upward, or toward the aperture of the ridge against which the hinge of the brachial valve rests. The tracks are conspicuous and exposed on the interior for almost the full length of the cone. Apically they are not covered to any great extent by adventitious shell.

Prominent on the inner surface of the sides are long hollow tubes that open proximally to the exterior although many of them have two or more openings on the inside. These seem to be rhizoid spines around which the shell has grown in its lateral and dorsal growth. These hollow spines have been engulfed in a manner similar to that of the protective spines on the margin of the cone. These interior spines are a universal feature of this genus and cover all surfaces of the interior, except the groove formed by the pseudodeltidium and associated structures.

The muscle area in *C. kingorum* forms an elongated mound at the apical end which descends in height toward the apex. This mound is marked medially by a narrow, rounded crest but this is not a septum because it is only slightly elevated. On the sloping sides near the base, and on the floor beside the mound, subflabellate scars marked by faint longitudinal lines are visible in a few specimens. These are taken to be traces of the diductor scars. Definite adductor scars are not clearly discernible although depressions on the side of the crest probably are traces of these scars. The crest of the muscle mound

is surmounted medially by one to three ridges in different specimens. Differentiation of individual adductor scars seems to be impossible but it is clear that the adductors were confined to the crest of the mound. The muscle mound is made up of cystose shell, and some of the exploded blisters forming newly formed cysts can be seen at the base of the mound on both sides and at the distal end.

The brachial valve of *Cyclacantharia* is essentially the same as that of *Hercosia* but some structures are developed differently. For example, the cardinal process is double-shafted but the two lobes are not connected anteriorly and commonly are greatly elongated. The process thus suggests that of *Echinosteges* with the long adventitious prongs extending anteriorly. The myophore is likewise bilobed, without any development of a median lobe. The myophore is roughened for a considerable distance. In this genus, development of a double ridge to buttress the cardinal process is very slight. Many specimens indicate the presence of this feature, but it is almost vestigial and frequently difficult to discern. The lateral ridges are also poorly developed but usually appear indistinctly. A chilidium covering the posterior part of the myophore is commonly present. This is not always completely preserved, but part of it at least can be seen in many specimens.

The endospines of this genus contrast strongly in number and size with those of *Hercosia*. Generally the endospines are short, stout, and striated, usually in a single row, but a second row appears in many specimens. As in *Hercosia*, the brevisseptum is almost obsolete, appearing as a thin remnant, not present in all specimens.

Although the adductor scars of the brachial valve are seldom thickened, a few old specimens show the individual marks to perfection. In these the anterior adductors are generally smooth and much smaller than the posterior pair, which lies outside of the anterior ones as well as posterior to them. The outer scars are subtriangular in outline and are usually strongly dendritic.

**GROWTH.**—The smallest or youngest *Cyclacantharia* consists of a flat expansion with a circular body cavity bounded by a slightly raised wall. The expansion adheres all around close to the substrate. The posterior is interrupted by a notch bounded on each side by a slightly flattened plate with a socket in the lateral wall on each side of the flat plate.

This is the initial palintrope and sockets to which the brachial valve articulates. Irregular blisterlike plates form on the outside of the inner ring and on the flat expansion. This is the beginning of the cystose layer between the inner body wall of the shell and the outer wall, which is not yet formed in the youngest specimen. In the next stage the outer edge of the flat expansion is deflected dorsally from the substrate and starts to grow vertically, thus producing an outer wall around the inner body ring. In this manner the palintrope to which the brachial valve is attached becomes surrounded posteriorly by the outer wall of the shell.

Many specimens have the inner ridge folded medially where it is in contact with the dorsal valve; it has been homologized with the pseudodeltidium. Growth of the shell makes this a concave path bounded by ridges representing the plates in which the sockets are located. In broken specimens, where the outer layer is peeled off to reveal the interior, the concave plate is still preserved. Some young specimens, in which growth has gone no more than a few millimeters, have the "pseudodeltidium" visible as a distinct plate adhering to the outer wall or separated by vesicular shell. The brachial valve operating against the "pseudodeltidium" has a chilidium over the cardinal process exactly as in many genera of the Strophomenida. The presence of this atavistic chilidium indicates that the homology of the structures of this part of the richthofeniid shell is clearly comparable with the Strophomenida.

Incipient anchor spines begin to form at 1 mm of height on the anterior side. At 3 mm the spines have begun to creep along the substrate. Appearance of protective spines on the inside of the margin takes place at an early stage, but is not uniform. In some specimens they appear at 3 mm of height but in others somewhat later. The ridges bounding the sockets are conspicuous at these early stages, during which the depth of the body cavity is not uniform, but is largely dependent on the situation in which the spat finds itself. In places where lateral development is possible it was broad and shallow, but specimens growing in more confined circumstances tended to develop a deep cavity.

Development of the muscle region of the pedicle valve is variable. In some specimens, especially broad and shallow ones, a pit is not always developed, but in others the cystose shell is built rapidly on the anterior side of the muscles, and a deep pit

forms. If the cystose shell is broken away anterior to the pit, the surface of the muscle attachment remains to form a bilobed plate reminiscent of the myocoelidium of *Richthofenia*.

### *Cyclacantharia gigantea*, new species

PLATE 295: FIGURES 1-6

Large tapering, variable cone, height about twice thickness; apical angle variable from  $35^{\circ}$  to  $60^{\circ}$ . Apex usually eccentric, thick, filled with cystose shell for about a third of height. Vestibule deep; aperture wide, moderately flared; nature of protective spines not known. Posterior side somewhat flattened. Brachial valve lying strongly obliquely. Surface moderately wrinkled.

Brachial valve nearly flat and with narrow hinge and short neck. Interior with small adductor field but moderately thickened scars. Endospines not seen.

Pedicle valve interior with pseudodeltidial region partially covered; muscle region not strongly thickened.

MEASUREMENTS (in mm).—From localities USNM 714t and 707a, specimens 151648 (holotype) and 151647 (paratype), respectively: apical angle  $60^{\circ}?$ ,  $35^{\circ}$ ; length 41.2, 26.4?; brachial valve length 35.3, (?); brachial valve width 36.5, (?); surface length 90.0+, 88.0+; hinge width 10.4, (?); midwidth 43.6, 33.8?; height 78.2, 86.0+; thickness 50.0, 47.0+; aperture length 45.4, (?); aperture width 60.0, (?).

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (base, top, and Decie Ranch Member).

LOCALITIES.—Skinner Ranch: (base) USNM 720e; (top) 722m. Decie Ranch: USNM 707a, 714t.

DIAGNOSIS.—Gigantic *Cyclacantharia* with height equal to about twice the length.

TYPES.—Holotype: USNM 151648. Figured paratype: USNM 151647. Measured paratype: USNM 151647.

COMPARISON.—The large size and proportions of this species distinguish it from all others described in this paper. The body chamber of the cup is nearly equal to the vestibule in height, a fact that makes this species different from the common Word forms and from *C. paucispinosa*, new species.

DISCUSSION.—This species is not based on a good supply of specimens, and all are imperfect. The

holotype, fortunately, is broken along the line of the interior of the brachial valve, permitting investigation of anatomical details. Unfortunately, none of the specimens gives any indication of the nature and abundance of protective spines on the cup margin. One imperfectly silicified specimen gives some details of the pedicle valve interior and of the long and massive apical cystose zone. This specimen shows that the pseudodeltidial area was partially covered by adventitious shell in the proximal region.

*Cyclacantharia kingorum* Cooper and Grant

PLATE 217: FIGURE 4; PLATE 298: FIGURES 9-19; PLATE 299: FIGURES 1-20; PLATE 300: FIGURES 1-25; PLATE 301: FIGURES 3-23; PLATE 308: FIGURES 6, 22, 23; PLATE 309: FIGURE 30

*Richthofenia permiana* Girty (not Shumard), 1909:283 (part), pl. 31: figs. 1-3.  
*Richthofenia permiana* Böse (not Shumard), 1916:36, pl. 1: figs. 1-17, pl. 2: figs. 8, 15, 17, pl. 3: figs. 1, 5-7.  
*Prorichthofenia permiana* R. E. King (not Shumard), 1931: 99, pl. 29: figs. 6-9, pl. 30: figs. 8-13.—Muir-Wood and Cooper (not Shumard), 1960:139, pl. 29: figs. 1-15.—Rudwick (not Shumard), 1961, pl. 72: figs. 1-14.  
*Cyclacantharia kingorum* Cooper and Grant, 1969:7, pl. 5: figs. 13-16.

Large variable cones with apical angle varying

from 20° to 55°; apex usually slightly eccentric; aperture normally not flaring. Vestibule moderately deep. Posterior side generally moderately flattened; anterior side broadly rounded; sides narrowly rounded; aperture generally transversely but broadly elliptical. Protective spines on anterior side usually long, commonly forked, stout, and longitudinally striated; protective spines on posterior side usually shorter and less stout than on posterior side; rhizoid spines long and stout. Surface strongly wrinkled concentrically. Apex usually with moderate cystose thickening.

Brachial valve generally flattened to slightly concave, with short neck, narrowly rounded sides, and broadly rounded anterior margin. Surface generally papillose to finely spinose.

Pedicle valve with strong aulacoterma and well-defined pseudodeltidial region completely open to interior; muscle field occupying thickened area at apex; muscle marks indistinct. Interior spines strongly developed on all walls except posterior one.

Brachial valve interior with small, bilobed, not strongly elevated cardinal process with strongly roughened myophore; chilidium present. Muscle marks usually not strongly impressed; endospines few and stout.

MEASUREMENTS (in mm).—

	apical angle	length	brachial valve length	brachial valve width	surface length	hinge width	midwidth	height	thick- ness	aperture length	aperture width	flange length
USNM 706e												
151786a	45°	23.8	17.0	22.0	42.0	7.0	27.7	39.0	29.0?	28.2	31.2	8.0
151786b	55°	25.0	17.0	24.0	42.0	6.5	31.4	32.6	21.9	21.5	36.7	?
151786c	36°	20.5	14.0	19.0	48.0	6.0	21.0	42.0	32.0	26.0	27.5	7.5
151786d	34°	22.3	15.0	21.5	44.0	?	26.4	39.6	29.1	24.2	32.8	4.0
151785e	24°	19.0	14.0?	18.0	51.0	6.0	20.7	53.0	44.0	18.8	24.0	?
151786f	41°	20.7	15.0	21.5	40.0?	7.5	27.8	40.0	29.0	23.4	28.0	?
151786g	45°	23.4	19.0	24.0	46.0	7.0	28.3	45.0	30.6	27.4	36.4	5.0
151786h	49°	21.7	15.0	19.5	36.0	6.3	24.6	31.5	20.7	24.4	32.5	4.0
151786i	31°	18.0	13.5	16.5	50.0	7.2	21.0	46.9	33.9	21.6	26.0	?
151786j	35°	17.0	14.0	15.5	32.0	5.5	19.4	25.0	16.0	20.8	23.4	?
151786k	46°	20.8	15.0	19.0	37.0	6.5	24.7	29.7	19.2	22.0	26.7	2.0
151786l	44°	15.4	13.0	16.0	31.4	6.0	20.6	19.9	13.7	20.0	24.3	?
151786m	54°	23.5	16.0	20.0	23.0	7.0	24.3	23.0	14.3	28.4	28.5	2.5
151786n	44°	20.0	14.0	20.0	35.0	5.5	25.7	25.2	17.5	19.0	26.7	?
151786o	45°	17.8	13.5	17.0	20.0	5.0	21.4	17.0	15.0	22.4	25.0	3.5
151786p	38°	11.5	8.0	11.0	20.0	3.5	13.0	16.4	11.0	11.6	14.8	?
151786q	37°	7.3	5.5	6.0	9.0	2.5	7.3	7.7	5.0	7.7	8.8	?
151786r	37°	6.5	5.3	6.5	9.5	1.8	8.7	5.9	4.3	8.0	10.2	?
151786s	37°	5.4	4.0	4.0	7.0	1.8	5.0	3.7	2.5	6.3	6.8	?





STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank, Willis Ranch, Appel Ranch members, and lens between the last two), Cherry Canyon Formation (Getaway Member).

LOCALITIES.—Word: USNM 731m, 731u, 732s. China Tank: USNM 703e, 706a, 706c, 706z, 726r, 733q. Willis Ranch: AMNH 505, 506; USNM 706, 706e, 723t, 723w, 724u, 731h, 735c. Lenses: USNM 706b, 732c, 737w, 742b. Appel Ranch: USNM 704, 706d, 714o, 715i, 716v, 719z, 722t, 726t, 727j. Getaway: AMNH, 21, 496, 519, 600; Moore 31; USNM 730, 732.

DIAGNOSIS.—*Cyclacantharia* having an average apical angle of about  $40^\circ$ , strong spines on the anterior side, and weak ones on the posterior side of the aperture.

TYPES.—Holotype: USNM 153831. Figured paratypes: USNM 123917a, b; 123918; 124138; 124139; 124140a, b; 124164a-c; 124165a; 124166. Figured hypotypes: USNM 124140c, d; 124168a; 151782a-c; 151785a-d; 151786v, w; 153832; 154054; 154063a-t; 154064a-m, o-r; 154535a, b. Measured hypotypes: USNM 151778a-j; 151781a-j; 151783a-m; 151786a-t, y; 151790a-g. Unfigured paratypes: USNM 151786a-u; 154064n.

COMPARISONS.—This species, because of its abundance and great variability, is difficult to distinguish from some other species of this genus. Its great variability, induced by the difficult conditions under which it lived, produces mechanical distortions similar to malformations and variations of other species. Isolated specimens can be identified specifically only with difficulty, if at all.

*Cyclacantharia kingorum* differs from *C. gigantea*, new species, in its much smaller size, although small specimens of the latter species might be similar to *C. kingorum*. Specimens of *C. gigantea* indicate a differently proportioned cup with the thickness slightly more than half the height, and a considerably rounder cross section; both criteria, however, are difficult to demonstrate, because of few and imperfect specimens.

*Cyclacantharia kingorum* is very similar to *C. robusta*, new species, but is slightly smaller and less robust, when the larger forms of both species are compared; and, on the average, the apical angle of the latter is greater than that of the former. Another difference, difficult of demonstration without a large series, is the more numerous but smaller protective spines around the inner margin of the

cup. Furthermore, *C. robusta* in the adult form has stronger and more numerous protective spines on the posterior side of the aperture.

*Cyclacantharia paucispinosa*, new species, which is generally a large form with wide angle and fairly smooth exterior, has an apical angle that averages greater than that of *C. kingorum* and the protective spines are generally shorter and less strong than those of *C. kingorum*. Generally, a strongly flared aperture is rare in the Leonardian species, whereas it is fairly common in *C. kingorum*. Inside the pedicle valve of *C. kingorum* the muscle mound is more strongly developed than that of *C. paucispinosa*.

DISCUSSION.—A fine series of this species from several localities permits description of its growth and variation. Growth will be considered in some detail, and this will be followed by a discussion of the species at a few localities representing different stratigraphic levels. Specimens of *C. kingorum* of minute size can be found attached to other richthofeniids or other shells of all kinds. The smallest specimen measures about 2 mm in diameter but the earliest stage of development may be seen in larger specimens, the course of development generally depending on the nature of the substrate to which they are attached. Generally the spat in favorable circumstances initially forms a spreading, irregular but generally crudely circular expansion adhering tightly to the substrate. Within this expansion is a slightly elevated rim, straight at the posterior end but broadly rounded laterally and anteriorly. The brachial valve fits into two slots on each side of the straight posterior margin and rests on the elevated rim. The spat then forms cysts, or blisters, on the outside of the inner elevated rim and the margin of the flat expansion turns up (dorsad) to form the outer wall of the shell. The anterior side usually grows faster than the posterior side and thus produces an unsymmetrical cone with the anterior side higher than the posterior side.

At an early stage the inner surface of the anterior side develops fine spines, the initial stages of the large protective spines covering the aperture. No uniformity in size has been detected in the development of this feature, some very small spat have the spines well developed but other larger ones lack any trace of them. Anchor spines are sent out at an early stage but again no uniformity was detected. Anchor spines were seen in some specimens

measuring only about 1 mm in height at the anterior margin.

Cystose shell forms at an early stage inside the shell and between the outer wall and the inner wall. Inside the shell, cysts appear on the anterior side of the apex and are rapidly built into a mound on which the muscles are attached. In some specimens these cysts collapse or fail to become silicified. Then the muscle field appears as a free bilobed plate extending into the living cavity and suggesting a myocoelidium. Usually, the cysts are not collapsed and form a mound on which the adductor muscle marks are located.

Cysts form in the young shell all around the rim of the body chamber but they are most developed at the angles into which the sockets of the brachial valve are inserted. Broken adults usually show a thin layer of cysts between the inner and outer walls on the anterior side. This layer thickens dorsally and is thickest in the posterolateral areas which form the ridges bounding the "delthyrial" cavity.

Development of the hood, or posterior wall, is extremely variable. In many spat, a low wall develops just dorsad of the hinge but this may not increase until a fair size has been attained. In many specimens, several millimeters of height are attained while the brachial valve is still marginal. The hood usually becomes established after it reaches 8 mm of height, but, rarely, specimens having heights of 10 and 20 mm have been seen with marginal brachial valves. The hood, once established, seems to catch up to the more anterior parts of the rim and forms an aperture with margins of uniform height.

The hood is the site of an interesting and often lavish deposition of cystose shell, especially when a change in the direction of growth of the hood takes place. With such changes the cystose shell is laid around the old generations of protective spines until they are completely buried and a new generation appears on the posterior margin. In some specimens this cystose zone becomes very thick, forming a prominent swelling on the dorsal side.

The large protective spines of this species are one of its striking characteristics. They are developed on all sides of the cup but appear earliest and are thickest on the anterior side. Some spines are almost hairlike, while others are stout and may branch several times to simulate a miniature staghorn. In most specimens the spines of the anterior side extend about halfway or less across the aperture,

and the spines on the posterior side are short and insignificant. In a few old specimens, however, the spines of the posterior side are also long, and meet the anterior spines across the cup, providing effective protection of the animal; but specimens of this sort are rare.

Characters of the interior are as variable as those of the exterior. Some specimens have numerous tubes on the inner surfaces while others have few. These tubes, furthermore, are a feature of the adult shell. The muscle region is variably thickened and the cystose shell under this position of the inner layer generally consists of long flat cysts rather than the small narrow ones developed elsewhere.

Inasmuch as the aperture of the pedicle valve of this genus is variable, this variability is reflected in the brachial valve, which closely fits the form of the body cavity. Brachial valves are generally wide shouldered and have moderately long necks to the narrow hinge. The articulating processes are small nubs at the ends of the hinge, and are inserted into sockets in the pedicle valve. Brachial valves are generally nearly as long as wide, but many specimens are present in the collection in which the length is greater. Young valves tend to have length and width nearly equal.

The exterior of the brachial valve is generally marked by strong granules or short spines. These are seen best in the young stages and appear to be worn off on the older shells. Inside the brachial valve the endospines are long and stout. Some specimens have a single row of them, but in others two rows are present. They are, however, never as numerous as in *Hercosia*. Between the muscle scars and the endospines most specimens have a few scattered nodes that appear to be incompletely resorbed endospines. The brachiopod must have resorbed early spines as it lay down new ones in the growth of the valve.

Perhaps the best way to record the variability of this species is to give notes on several of the localities. The specimens from each locality have some interesting character that distinguishes each from the other, yet they all appear to comprise a single species.

USNM 706e: The average specimen from this locality has an apical angle of  $41^\circ$  and its width at the aulacotermia is slightly greater than the length but the brachial valves average slightly wider. The height is generally 1.3 times the width and the body

occupied 0.72 of the height. The aperture of the adult is well provided with spines, but those of the posterior side are usually less numerous and not so strong as those of the anterior side. Specimens from this locality attain a height of over 50 mm, but such size is rare. Measurements between 35 and 45 mm are more common. The apical angle varies from  $30^{\circ}$  to  $54^{\circ}$  but one measurement of  $24^{\circ}$  was recorded, representing a long slender specimen that must have lived squeezed among its neighbors.

USNM 706: Specimens from this locality strongly resemble those from the previous one, which is not surprising because they come from the lower part of the Willis Ranch Member (= Third Limestone Member) of the Word Formation. When examined en masse, specimens from this locality appear, in general, to be smaller than those from USNM 706e. The largest specimen measured had a height of 43.5 mm but it is a long, slender, narrowly tapering form. The largest specimen having more normal proportions measured 40 mm in height. The average length/width ratio is like that of USNM 706e, but brachial valves tend to average slightly narrower. The height, moreover, is 1.4 times the width and the body chamber tends to occupy somewhat more of the cup than in specimens from USNM 706e. The protective spines around the inner margin of the cup generally are few and appear to be more delicate. No massive spines were seen on old shells. Spines are developed somewhat sporadically on the posterior inner side of the cup and, when they do appear, are usually small and delicate. The range of variation in the apical angle is  $32^{\circ}$  to  $44^{\circ}$  in adult specimens.

USNM 706b: This locality is composed of rocks slightly younger than those of USNM 706 and 706e, but the specimens from it are very similar to ones from the other two. The apical angle varies from  $32^{\circ}$  to  $50^{\circ}$  and averages about  $39^{\circ}$ . The length/width ratio indicates a nearly round cross section at the position of the aulacotermia. The brachial valves of the measured specimens average a little wider than those of the two previous localities. The relationship of height to width is nearly the same as that noted in specimens from USNM 706 but the body chamber occupies 0.69 of the height.

USNM 706c: The largest specimens of this species known were taken at this locality; one measures 55.5 mm in height. Other specimens, although not attaining that height, are unusual for the large

aperture recorded. The apical angle averages  $41^{\circ}$  and has a range of  $29^{\circ}$  to  $51^{\circ}$ . The length/width ratio is 0.82 and that of the brachial valve is slightly less (0.79). The height is 1.4 times the width on the average and the body occupies 0.7 of the height. Spines are generally not well developed on the posterior inner side of the cup and, when present, are small. The most striking adults are the few stout cones with high apical angle and very wide aperture. This type and the thick-shelled and unusually large normal adults characterize the locality.

USNM 714o: Specimens from this locality have a nearly round cross section at the aulacotermia and a length/width ratio of the brachial valve of 0.83. The height is 1.3 times the width and the body cavity is 0.73 of the height. Specimens are not as numerous at this place as at the other localities and attain somewhat more modest size than recorded at USNM 706e and 706c.

### *Cyclacantharia kingorum agaricoidea*, new subspecies

PLATE 298: FIGURES 1-8

This name is suggested for specimens that appear to be an aberrancy from the normal *C. kingorum*. They are characterized by an enormous flaring of the apertural margin to produce a mushroomlike form. The circle of protective spines is like that of the common subspecies.

MEASUREMENTS (in mm).—From locality USNM 706b, specimens 151780a (holotype) and b, respectively: Length 23.2, 18.8; midwidth 28.0, 23.7; thickness 25.0? 22.0?; height 43.0+, 32.0; aperture length 38.3, 33.4; aperture width 50.0, 40.4.

STRATIGRAPHIC OCCURRENCE.—Word Formation (lens between the Willis Ranch and Appel Ranch members).

LOCALITY.—706b.

DIAGNOSIS.—*Cyclacantharia kingorum* with widely flaring aperture.

TYPES.—Holotype: USNM 151780a. Figured paratypes: USNM 151780b, c. Measured paratype: USNM 151780b.

### *Cyclacantharia paucispinosa*, new species

PLATE 294: FIGURES 34-37; PLATE 296: FIGURES 1-21; PLATE 297: FIGURES 1-8



Large variable cones with apical angle varying from 37° to 61° and usually with blunt twisted apex. Aperture generally not flared. Vestibule fairly deep, occupying about 0.3 of height, body chamber occupying remainder. Cross section nearly circular, posterior side slightly flattened. Sides rounded; anterior broadly rounded. Protective spines not strongly developed, ranging from slender to short and stout, usually sparsely distributed and seldom well developed on posterior side. Rhizoid spines long and stout. Surface usually with some concentric wrinkling but fairly smooth in many.

Brachial valve with fairly wide hinge, but usually short neck and smooth surface in adults. Slightly concave in profile.

Pedicle valve interior with posteriorly thickened aulacotermia having median thickening which forms reentrant in brachial valve margin; posterolateral areas large and rounded forming rounded ridges bounding pseudodeltidial region. Pseudodeltidial region partially covered but dorsad portion well defined. Muscle mound not greatly thickened, with double ridge on crest in some specimens. Apex moderately thickened, cystose plates long and flattened.

Brachial valve with large cardinal process having strongly developed chilidium; lateral ridges strong, extending to midvalve. Median buttress ridge present, not strong; adductor scars moderately large, dendritic. Endospines few, anterior in position.

#### MEASUREMENTS (in mm).—

	<i>apical angle</i>	<i>length</i>	<i>brachial valve length</i>	<i>brachial valve width</i>	<i>surface length</i>	<i>hinge width</i>	<i>midwidth</i>	<i>height</i>	<i>thick- ness</i>	<i>aperture length</i>	<i>aperture width</i>
USNM 702c											
151766a	50°	29.0	22.0	26.4	45.0?	8.8	32.6	34.5	24.0	33.6	34.8
151766b	47°	25.8	20.0	18.0	50.0	6.0	24.7	36.0	26.4	29.3	28.0
151766c	51°	24.0	18.0?	24.0?	53.0	8.4	29.0?	36.0	24.6	25.6	31.3
151766d	46°	21.5	18.0	23.5	54.0	6.2	29.6	33.9	20.5	30.4	30.0
151766e	43°	24.3	?	22.0	45.0	?	24.6	38.3	26.7	17.6	25.7
151766f	50°	25.6	21.0	21.0	46.0	7.0	30.2	33.6	20.3	27.5	30.0
151766g	44°	21.5	16.0	19.5	40.0	6.3	25.0	33.8	21.0	22.6	26.7
151766h	53°	23.5	17.0	21.5	34.0	7.5	23.0	28.2	18.2	26.4	32.0?
151766i	38°	21.0	17.0	19.0	36.0?	5.5	23.5	33.0	24.5?	26.5	28.0
151766j	49°	30.5	20.2	24.5	45.0?	9.8	31.6	36.0	27.6	41.8	41.0
151766k	40°	29.3	21.0	23.0	60.0	5.8	30.0	39.6	29.0?	25.2	32.0
151766l	61°	24.6	18.0	27.0	31.0	6.5	29.9	19.0	12.7	28.8	34.0*
151766m	54°	24.2	16.0	20.0	42.5	7.3	26.6	31.0	23.2	25.0	28.5
151766n	37°	19.7	13.5	16.0	35.0	5.5	21.5	26.8	18.4	18.8	22.4
151766o	49°	19.5	15.0	18.5	31.0	6.0	22.8	22.0	16.4	20.9	24.4
151766p	46°	24.6	17.0	22.0?	59.0	?	29.7	45.0	29.3	23.5	27.8
151766q	42°	23.2	16.0	23.8	44.0?	9.0	29.2	30.9	23.4	25.4	34.0
151766r	41°	33.5	25.0	23.0	62.0	8.2	31.9	36.0?	28.7	40.5	36.4?
151766s	54°	19.0	16.0	21.5	32.0	5.8	26.0	26.4	15.0	29.2	35.0
151766t	60°	25.7	20.0	24.0	43.0	6.5	30.3	33.0	22.4	30.7	38.5
(holotype)											
151766u	39°	20.0	15.5	22.0	51.0	7.3	24.5	31.5	27.7	22.3	28.0
USNM 703a											
151768a	49°	26.4	18.0?	20.3	48.0	7.3	27.6	48.0	31.0	31.2	34.5
151768b	50°	24.5	16.0	27.5	55.0	7.5	29.6?	38.4	23.9	28.9	37.4
151768c	47°	22.0	16.0	21.0	47.0	6.0	26.8	37.3	26.5	26.7	27.5
151768d	51°	21.0	16.0?	25.0	51.0	7.3	28.1	44.0	31.2	30.4	34.0
151768e	46°	23.3?	17.5	21.0	45.0	8.5	28.0?	43.0	30.0	36.0	32.0
151768f	51°	22.7	19.0	23.5	38.0	8.0	26.0	31.0	22.8	29.3	31.2
151768g	53°	22.7	19.0	26.0	32.0	7.3	31.9	29.0	20.7	26.4	33.2
151768h	53°	21.5	16.2	21.0	30.0	5.0	24.5	21.0	14.4	24.4	29.4
151768i	58°	23.7	17.0	22.0	40.0	5.5	29.3	30.0	18.6	?	?
151768j	45°	26.8	22.0?	24.0	50.0?	8.0	26.6	38.9	26.0	28.2	31.0
151768k	53°	15.5	12.2	16.0	28.0	4.5	17.4	19.0	13.3	22.2	27.4

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation, Road Canyon Formation.

LOCALITIES.—Cathedral Mountain: USNM 703b. Road Canyon: AMNH 503, 507; USNM 702c, 703, 703a, 703c, 703d, 708c, 716x, 719x, 721s, 721t, 721y, 726f, 726z, 726za, 732m.

DIAGNOSIS.—Large, generally wide *Cyclacantharia* with large apical angle and few protective spines around the inside margin of the cup.

TYPES.—Holotype: USNM 151766t. Figured paratypes: USNM 151765a-e; 151766a, b, q; 154060a, b; 154061a-c, e; 154062a, b; 154065. Measured paratypes: USNM 151766a-s, u; 151768a-k. Unfigured paratypes: USNM 151766c-p, r, s, u; 154061d.

COMPARISONS.—In highly variable shells, especially those in which the variation is induced by inhospitable living conditions, specimens of each species will strongly resemble certain types of variants of the others. This species has individuals strongly resembling some of the variants of *C. kingorum* Cooper and Grant and *C. robusta*, new species, but the average of each species is quite unlike the average of the others. *Cyclacantharia paucispinosa* differs from *C. kingorum* in the lesser development of the protective spines around the inner margin of the cup, in the larger apical angle, and in the generally wider and more circular cup. The apical angle of the Road Canyon species is not greatly different from that of *C. robusta*, but the difference in the degree of development of the protective spines is strong. The brachial valves of *C. paucispinosa* are not internally nodose as in *C. robusta*, the development of the muscle mound is much less, and *C. paucispinosa* has few internal spine tubes.

DISCUSSION.—Shells of this species are very distinctive, with their generally wide cups, thin shell, few spines, and often somewhat nude appearing exterior. Generally they are thinner than those of the other species of *Cyclacantharia*. This is especially true of specimens from USNM 702c which have almost paper-thin margins to the vestibule especially in young adults. In many specimens the mouth is very wide and expanded rather than contracted as in many specimens of *C. kingorum*. The spines on the inner rim of the cup are generally somewhat scattered, usually varying from delicate to moderately stout, but seldom ponderous and like stag-horns in *C. kingorum* and *C. robusta*. Furthermore,

the largest spine seen measures about 11 mm. Inasmuch as the spines generally are directed at an angle to the cup margin and thus project obliquely rather than directly across the orifice, they do not cover the opening of the cup as they do in *C. kingorum* and *C. robusta*. The rhizoid spines of this species appear to be generally located below (ventrad) the aulacoterma and thus leave a fair portion of the cup nude. This fact, together with the smooth unwrinkled character of some of the specimens, lends a rather bare appearance to the cups. These two characters give the species a readily recognizable appearance.

The interior of the pedicle valve is distinctive, compared to that of *C. kingorum* and *C. robusta*, having some features varying from these species. Most specimens of the pedicle valve are long, and fairly thin-shelled, and do not have a strong apical thickening. A few that have grown crowded between their bretheren, however, are elongated and have a thick, cystose apex. Inside, the muscle mound is seldom thickly developed, and the plates comprising it are usually long and flat. In some, the mound has a double-ridged crest, but other evidence of the muscle scars was not observed.

A striking difference between this species and the two large forms from the Word Formation is the poor development of the tubes on the inner shell wall. These, when present, are generally few and scattered and appear just dorsad to the distal end of the muscle mound. None were seen occupying the upper or dorsad portions of the living chamber. In some specimens the ends of the tubes extend into the body chamber and are free of the wall, rather than prone as in the Word species.

The interior of the brachial valve is characterized by a large and well-formed cardinal process but only a few endospines are arranged in a single row just inside the anterior margin. Another unusual feature is the fairly well marked presence of the brevisseptum which is usually not clearly seen in the Word species. Large specimens have well-thickened and strongly dendritic adductor scars.

### *Cyclacantharia robusta*, new species

PLATE 295: FIGURES 7-13; PLATE 297: FIGURES 9-19; PLATE 302: FIGURES 1-32

Large variable cones with apical angle varying from 30° to 54°, averaging about 45°, apex pointed

to bluntly rounded; aperture in adults with moderate flare; vestibule moderately deep; body cavity is 0.7 of height. Cross section at aulacotermia almost circular (length/width ratio is 0.90). Posterior side slightly flattened; anterior side broadly rounded and sides rounded. Protective spines on anterior strong and well branched, often thick; spines on posterior side in adult specimens usually large, occasionally massive. Rhizoid spines long and stout. Surface with strong concentric wrinkles.

Brachial valve flat to moderately concave in larger specimens with short necks and broadly

rounded sides; anterior margin gently rounded to nearly straight. Surface usually smooth in adults.

Pedicle valve interior with strong shelflike aulacotermia; pseudodeltidial area facing interior, wide and deeply grooved. Muscle field with strong moundlike adductor field and moderately deep diductor impressions. Mound with single or double ridge on crest. Interior spine tubes numerous on entire interior except in pseudodeltidial region.

Brachial valve interior with strong lateral ridges; large cardinal process, slight brevisseptum, and few large, stout endospines.

#### MEASUREMENTS (in mm).—

	apical angle	length	brachial valve length	brachial valve width	surface length	hinge width	midwidth	height	thick- ness	aperture length	aperture width	flange length
USNM 728												
151646a	54°	30.2	17.0	27.0	49.0	9.3	33.6	49.2	34.4	36.0	46.5	8.0
151646b	49°	34.7	23.0	26.5	45.0	8.5	35.2	43.2	33.3	36.0	42.7	7.0
(holotype)												
151646c	54°	25.8	16.0	24.0	36.0	7.3	31.4	33.0	21.9	33.2	36.9	11.0
151646d	43°	21.4	16.0?	45.0	23.0	?	28.2	42.3	28.0?	25.3	31.4?	7.0
151646e	24°	18.6	11.0	16.0	43.0?	7.5	19.3	45.0	34.0	18.6	21.4	?
151646f	38°	22.9	21.0	21.2	46.0	6.3	24.2	43.0	28.5	32.0	29.1	?
151646g	38°	22.3	15.0?	21.5	42.0	6.5	26.6	42.4	29.0	26.5	34.6	9.6
151646h	43°	28.2	22.5	26.5	52.0	5.8	31.4	39.6	24.3	28.3?	34.0	6.0
151646i	49°	24.6	17.0	26.0	45.0	9.0	30.4	40.0	28.0	22.6	35.7	4.0
151646j	50°	23.4	16.5	25.0	30.0	7.0	27.8	26.0	17.5	28.0	32.5	?
151646k	37°	20.6	14.0	38.0	16.0	6.0	21.8	31.0	21.0	22.6	25.0	5.0
151646l	48°	16.6	13.5	17.5	31.0	5.5	19.6	20.4	12.0	22.7	26.9	?
151646m	38°	14.0	11.0	14.0	20.0	4.0	16.0	19.0	14.6	15.3	18.0?	?
151646n	?	7.7	6.0	7.0	10.0	2.5	7.7	6.4	5.2	8.9	9.7	?
151646o	52°	36.3	?	?	47.0	?	36.0	48.0	36.8?	35.3?	45.0?	?

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Limestone Member).

LOCALITIES.—AMNH 496, 512 (= USNM 728), 600.

DIAGNOSIS.—Large, stout *Cyclacantharia* having an average apical angle of about 45° and stout protective spines around the cup rim in adults.

TYPES.—Holotype: USNM 151646b. Figured paratypes: USNM 151645a, b; 151646a, e, g, j; 154059a-g, i-p, r-u. Measured paratypes: USNM 151646a, c-o. Unfigured paratypes: USNM 151646c, d, f, h, i; 154059h, q.

COMPARISON.—This species is most like *C. kingorum* Cooper and Grant and shares some features with it. The relationship of the height to the body cavity is the same as that of *C. kingorum* and the ratio of height to width is most like that of *C.*

*kingorum* from the Word Formation (China Tank Member, USNM 706c) rather than like the more typical forms such as those at USNM 706e. The apical angle averages higher than normal in *C. kingorum* and the adults attain a length of 50 mm, but none have been found which attain a length equal to those at USNM 706e in the Glass Mountains. The protective spines of *C. robusta* are very large and massive, covering the large aperture, and the spines on the posterior side on the hood are generally more massive and longer than those of *C. kingorum*.

*Cyclacantharia robusta* can be distinguished readily from *C. paucispinosa*, new species, by the bare appearance of the exterior of the latter, its generally greater apical angle, the smaller and less robust protective spines, and the generally lesser

development of the muscle mound in the apex of the pedicle valve. The brachial valves of the two are also unlike, because *C. robusta* has a stronger development of endospines but the adductor scars are not so strongly thickened and dendritic as in *C. paucispinosa*.

DISCUSSION.—This species has no features not seen on other richthofeniids but it has some of them exceptionally developed, such as the interior tubes on the body wall, the pedicle valve muscle field, the protective spines, rhizoid spines, aulacoterma, and the shell.

The body wall of many specimens between the apex and the aulacoterma is covered by longitudinal tubes. These are strongest posteriorly and disappear into the shell wall at various places to emerge on the exterior as a rhizoid spine, some of considerable length. The passage of the spines through the cystose layer and outer shell wall can be seen in numerous specimens. Sections near the base of the cup show spines within the cystose layer of the muscle mound and at any other part except the pseudodeltidial region. The cysts cling to the outside of the tube and effectively cover it. In some, the tubes are superimposed on one another, a short one extending into the cystose layer and at the place where it passes into that layer, and a new tube begins with an opening at about the end of the previous tube. This gives some of the tubes the appearance of having one or more openings. The tubes do not appear until a fairly late stage in development, early adulthood. These tubes appear to be identical to those developed in many productid genera, such as *Liosotella*, which appear on the inner lateral slopes anterior to the ear baffle, and *Waagenoconcha* as described by Grant (1966b).

Some specimens of *Cyclacantharia robusta* show actual scars of the muscles. The diductor scars thus appear to lie on the sloping faces of the muscle mounds in the apex. The muscle mounds are built of cystose shell, the cysts being large blisters. The later ones formed on the outside of the mound facing the aperture are somewhat conical in form. The adductors appear to have been attached to one or two linear ridges that lie on the crest of the mound.

At a fairly early stage in the development, protective spines form in the granular zone around the inside of the vestibule, above the aulacoterma. Several rows of them form as small knobs and

gradually lengthen with age. In late stages of shell growth the posterior side produces cysts around old spines as the animal migrates in a dorsal direction in its shell. Many of the cysts bear small spines that appear to be incipient protective spines. These resemble taleolae very strongly, and it is possible that the spines are a modification and elaboration of taleolae. The granules around the inner vestibule are taleolae, and evidence points to their presence on the layer lining the wall of the body cavity.

Broken protective spines have a radial or stellate structure in the interior and there also is a different color between the main shell substance of the spine and the radial structures, the latter appearing as a white star in some of the specimens that are broken across. A central axis makes a round hub for the wheel from which seven spokes radiate. On the exterior the spokes stand up as elevated lines, thus producing a striated appearance. The spokes appear to be harder or more resistant than the matrix between them, thus emphasizing the ribbed appearance of the spine (USNM 151646 h, j). Because of their silicified state, it is difficult to make any statement regarding the nature of the two elements making up these spines, nor does the collection include any unsilicified material that could be sectioned.

Several specimens have the rhizoid spines well enough preserved to show some of their characteristics. These spines generally are simple tubes but, where passing over obstructions are often flattened or otherwise distorted. In other places they swell to double or more their normal size. Many of them flatten and widen on making contact with substrate, spreading out distally and thus effecting a stronger hold on the bottom. In some instances spines coalesce where their ends meet, but no example of branching was seen. Although the spines are effective holdfasts, they also serve in the economy of space in the sea as dwelling sites for innumerable small invertebrates, and for the spat of *Cyclacantharia*. The spines of some also became traps for small shells that were killed when ultimately their brachial valves could not be moved, so the shells could not grow normally (see pl. 292: figs. 1, 2; pl. 116: fig. 8).

The aulacoterma of adults is usually thick and forms a prominent ridge around the inside of the shell at the dorsal end of the body cavity. Broken specimens that show the whole interior of the body



cavity commonly exhibit a succession of rings around the body wall representing several generations of aulacoterma. The distance between these shows the extent of growth of the shell during certain periods, but it is not possible to determine how long each period was.

Most stages of growth are preserved in specimens of this species. They exhibit the same types of variation seen in *C. kingorum* but few subcylindrical forms were developed, suggesting that *C. robusta* was not so crowded in its early stages as *C. kingorum*.

### *Cyclacantharia transitoria*, new species

PLATE 294: FIGURES 19-33

Medium to fairly large variable cones, apical angle varying between 25° and 75°, averaging about 45°. Cross section at aulacoterma roundly elliptical, cup slightly flattened on posterior side; cup usually high, but depends on position in colony. Apex of high slender specimens considerably thickened by cystose shell, those with broad apical angle less so. Body chamber occupying about two-thirds of height.

Aperture with slight to moderate flare. Protective spines forming complete ring in old adults, with thick and erect spines on hood, but these sporadic in young adults. Protective spines usually short and stout. Rhizoid spines not numerous, slender to moderately thick.

Pedicle valve interior with thick aulacoterma and entire interior thickened in adults, strong antero-median ridge in many specimens. Psuedodeltidial area fairly wide, with moderately strongly rounded margins; muscle mound low, slightly thickened, not greatly elongated. Internal spines rare. Postero-lateral platforms small and narrow.

Brachial valve flat posteriorly but gently concave, anterior reflected dorsally in anterior third. Neck short, reentrant not deep; shoulders sloping and sides anteriorly narrowly crowded.

Brachial valve interior with large and thickened, often elongated cardinal process in old specimens; adductor scars thickened, anteromedian scars smaller than posterior pair. Brevisseptum strong in some specimens; endospines stout, bordering anterior margin. Myophragm low, double ridge, chidium strongly developed.

#### MEASUREMENTS (in mm).—

	apical angle	length	brachial valve length	brachial valve width	surface length	hinge width	midwidth	height	thick- ness	aperture length	aperture width
USNM 721z											
152690a	45°	17.2	?	?	39.0	?	21.6	32.8	?	12.6	17.5
152690b	65°	24.0	?	?	32.0	?	29.1	25.4	?	20.3	25.9
152690c	42°	19.6	13.0	20.6	33.0	?	24.3	27.4	21.0	16.0	22.0
152690d	62°	20.9	?	?	26.0	?	23.9	18.0	?	18.5	22.8
USNM 726d											
152693a	45°	24.4	?	?	38.0	7.0	31.6	35.5	?	13.4	21.4
152693b	30°	24.0	11.3	14.0	37.5	4.8	23.3	29.9	20.6	13.3	17.3
USNM 724c											
152691a	45°	20.8	13.2	16.3	32.0?	6.0	23.4	28.2	18.8	16.2	19.4
152691b	55°	20.7	14.5	16.3	36.0	6.0	24.4	27.8	18.5	16.6	22.6
(holotype)											
152691c	58°	16.4	?	?	22.0	5.2	19.6	16.2	?	13.0	16.8
USNM 721j											
152692a	34°	19.4	14.5	17.3	35.0+	7.3	23.5	32.0?	22.5	17.5	21.3
USNM 710u											
151654a	47°	19.8	13.5	22.2	40.0	8.0?	27.4	36.6	22.9	22.7	27.8?
151654b	75°?	21.5	14.0	21.5	33.0	7.3	25.9	35.0	23.0	29.7	?
151654c	39°	21.4	15.5	17.5	33.0	8.5	20.5	28.7	18.0	27.3	25.0
151654d	38°	18.4	12.0	20.0	38.0	5.0?	21.2	32.3	23.4	19.7	25.3
151654e	32°	16.9	13.2	14.0	44.0	?	18.0	43.7	24.0	22.4	?
151654f	31°	13.3	11.0?	13.0?	31.0	?	16.0	25.6	?	?	?
151654g	37°	12.0	10.3	14.8	21.0	5.0	15.9	26.3	18.2	14.8	18.0
151654h	37°	13.0	9.5	13.0	20.0	4.8	12.8	18.0	11.0	14.3	15.0?

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—AMNH 503; USNM 700v, 706f, 707e, 710u, 713, 716xa, 720d, 721j, 721r, 721w, 721x, 721y, 721z, 722e, 723x, 724a, 724b, 724c, 724j, 726d, 726e, 732i, 732j, 736x.

DIAGNOSIS.—Medium sized *Cyclacantharia* with moderate apical angle and development of protective spines spasmodic on the posterior side.

TYPES.—Holotype: USNM 152691b. Figured paratypes: USNM 152691a, c; 152692a; 152693b. Measured paratypes: USNM 151654a-h; 152690a-d; 152691a, c; 152692a; 152693a, b. Unfigured paratype: USNM 152693a.

COMPARISON.—This species more nearly suggests *C. kingorum* Cooper and Grant than any of the other species of this genus. It differs in a lesser development of protective spines on the posterior side of the cup and a generally smaller size. Fewer internal spines appear in *C. transitoria* than in *C. kingorum*.

DISCUSSION.—This species is not as abundant as *C. kingorum*, and it has therefore been impossible to define its characters as well as those of the Word species. Brachial valves from USNM 710u have a very obese cardinal process and an unusually large development of the brevisseptum. Furthermore, the chilidium is very well developed in this species. The cardinal process in some specimens has the lobes greatly elongated anteriorly. This characteristic is strongly reminiscent of a similar process in the aulostegids.

### *Cyclacantharia* species 1

Variable but usually long and slender cones with long cystose apex; apical angle small, varying between 20° and 40°. Cystose part occupying about one-third of height. Cross section variable, generally elliptical. Body chamber greatly elongated. Aperture generally not flared. Protective spines not seen; rhizoid spines not preserved.

Pedicle valve interior with very narrow pseudodeltidium; pseudodeltidial area covered only apically; muscle mound not strongly developed.

Brachial valve moderately long necked; shoulders narrowly rounded. Interior not known.

Described and measured specimen: USNM 152689.

MEASUREMENTS (in mm).—From locality USNM

720e, specimen 152689: apical angle 38°, length 21.6, surface length 47.0, midwidth 27.5, height 48.5+.

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (base).

LOCALITY.—USNM 720e.

DIAGNOSIS.—Elongate cones with high body chambers, low muscle mound, and narrow pseudodeltidium.

COMPARISON.—This species is more slender than other described *Cyclacantharia*. It resembles the higher specimens of *Hercosia uddeni* which R. E. King described as *Prorichthofenia likharewi*, but the latter has a strong apical septum and not so high a body chamber.

DISCUSSION.—This species occurs scattered among the *Scacchinella* and other bioherms that are abundant at USNM 720e. It forms small clusters and patches of very closely attached individuals. This very intimate growth evidently accounts for the extremely high cups that are so characteristic.

### *Cyclacantharia* species unidentifiable

Several small lots of *Cyclacantharia* are impossible to place in the species described above. Some of these are undoubtedly new species but considerably more material would be needed to demonstrate this. The specimens are listed by locality.

SPECIES 2 (USNM 728f).—This locality includes specimens similar to fragmentary ones from AMNH 628, 629, and 631, which are from the same stratigraphic level in the Bone Spring Formation and very close to USNM 728e. The specimens are all fairly erect cups with a fairly deep body chamber and therefore not referable to *Acritosia*. In most of the specimens the posterior side is not well preserved but in one of them (AMNH 631), an obese specimen preserving only the posterior side, thick spines overhang the hinge.

Described specimens: USNM 155032.

SPECIES 3 (USNM 746).—Several specimens have the cup short, with wide aperture and large apical angle. The specimens do not have a median septum and the hood of the posterior side is not preserved on any of them.

Described specimens: USNM 151635.

SPECIES 4 (USNM 702d).—A small single cup attached to a bryozoan branch has a complete circle of delicate spines around the inside of the aperture.

The specimen is only 11 mm in height, but the complete circle of protective spines suggests an adult.

Figured specimen (Pl. 294; figs. 17, 18): USNM 154053.

**SPECIES 5 (AMNH 404).**—A fine specimen about 30 mm high and with a nearly circular cup is a definite *Cyclacantharia* because it has a complete circle of spines around the inside of the cup. The spines are short and thin but occupy a zone of at least 5 mm.

Figured specimen (Pl. 308; figs. 7–9): USNM 151641.

**SPECIES 6 (AMNH 417).**—This lot consists of 20 specimens of assorted sizes. The adult is a high cup (30 mm or more) with elliptical aperture. The shell is stout; the muscle region of the pedicle valve is thickened and generally surrounded by numerous interior spines. Spines appear around the inside of the cup but are small on the posterior side. The brachial valve has stout but subdued endospines and an obscure brevisseptum.

The stratigraphic occurrence of this lot is doubtfully quoted as Carlsbad Limestone. If this is the correct horizon, the range of the genus into the Capitan-Carlsbad is established.

Described specimens: USNM 151642.

### *Taphrosestria*, new genus

[Greek *taphros* (ditch) + *sestron* (sieve)]

Small, squat, irregular cones with rounded base and wide flaring aperture. Brachial valve forming lip deep within cone, surmounted by high vestibule. Inner marginal wall of anterior side with flat anastomosing spines, commonly united closely and extending nearly across aperture, leaving narrow channel on posterior side; lip of cone sulcate on posterior wall of cup. Hood large, thickened and cystose. Exterior strongly rugose and squamose, squamae formed by successive margins of aperture (cone-in-cone structure). Anchor spines round and stout.

Pedicle valve interior with palintrope; aulacotermia strong and thick. Apex thickened by triangular muscle area; diductor scars outside adductors, triangular, attached to fluted plate overhanging lateral cavities. Adductor field thick and solid, slightly elevated above diductors. Adductors elongate, consisting of anterior and posterior pairs. Me-

dian myophragm small. Pseudodeltidial area short, open to interior. Internal spines large, short, numerous.

Brachial valve coarsely granulose to spinose on exterior; interior with strong, fairly erect but bilobed, short-shafted cardinal process. Region between cardinal process and adductor field thickened; median buttress ridge double, but indistinct. Adductor scars moderately thickened, consisting of inner anterior pair and outer posterior pair. Brachial ridges, when preserved, extending obliquely anterolaterally; endospines marginal, reduced. Brevisseptum reduced and indistinct.

**TYPE-SPECIES.**—*Taphrosestria peculiaris*, new species.

**DIAGNOSIS.**—Cyclacanthariidae with specialized protective spines, thickened muscle area in the pedicle valve, and extended pseudodeltidial region.

**COMPARISONS.**—The small size and squat appearance of these cones resemble *Teguliferina* Schuchert and LeVene and *Acritosia* Cooper and Grant. *Taphrosestria* differs in the form of the protective spines and the circulation channel produced by them on the posterior side of the cup. It also differs from *Teguliferina* in not having the flattened anchor spines so characteristic of that genus and in having well-developed cystose tissue in the apex. It differs from *Acritosia* in the character of the pedicle muscle field, details of the brachial valve, and the greater development of the pseudodeltidial region.

*Taphrosestria* differs from *Cyclacantharia* in not having a complete ring of spines around the inside margin of the cup, although it agrees with it internally. It also differs strongly from *Hercosia*, which it resembles externally, in not having the strong knife-edge median septum in the pedicle valve.

*Taphrosestria* appears to be intermediate between the Teguliferinidae which it resembles in its exterior form, and the Cyclacanthariidae or Hercosiidae in its cardinal process.

**DISCUSSION.**—This is one of the most peculiar of all the Glass Mountains brachiopods. Its squat form and spreading apertural margin combined with the nearly complete cover of flat anastomosing spines is distinctive.

The form of the cup of *Taphrosestria* is variable, but the degree of variability seems not to be so great as in *Hercosia*, or in *Hercosestria*. Some specimens of *Taphrosestria* are low and spreading, but others form fairly erect cones. Generally the surface of

attachment is irregular and fairly broad. The bases do not come to a point as in the more narrowly conical forms, consequently, it is difficult to measure an apical angle for specimens of *Taphroestria*. The name was given in allusion to a well-marked groove on the posterior, or hood side, of the cup that is conspicuous in some specimens but not all of them. This small trough, often tubular, is located under the extremities of the anastomosing protective spines and thus probably formed an excurrent channel during feeding. The incoming channel in feeding would be through the spines.

The protective spines are broad and flat and as they spread across the anterior side of the cup toward the posterior side they may unite and thus form a fairly solid network. The spines do not unite with the entire posterior side of the margin. Some of them attach to the inner sides of the cup margin and to the lateral parts of the posterior margin, but are left free over the posterior groove. In some specimens the anterior side of the aperture is covered by a solid plate or roof for as much as a half of the aperture. This is caused by a solid sheet of shell material not differentiated into individual spines at its origin. In these examples individual spines form far out over the aperture, thus the aperture may become greatly restricted.

Some details of the interior are as strange as those of the exterior. The aulacotermia of the pedicle valve is generally very thick and commonly is elevated medianly into a low median ridge that forms a notch in the anterior margin of the brachial valve. The pseudodeltidial area in its details is exactly like that of *Teguliferina*, but *Taphroestria* differs in being extended dorsally to a modest degree as the shell grows. Therefore, on the inside of the posterior wall a pseudodeltidial area like that of the prorichthofeniids, only shorter, may be seen.

Of considerable interest is the ventral muscle area which is better developed than in most related genera. Generally this area is fairly well elevated but it is commonly deeply excavated laterally so that the attachment parts of the diductor scars are thin plates, often elaborately fluted at their margins. The median part, where the adductors are attached, is cemented solidly to the floor and the muscle scars, which were elongate, are separated by a low myophragm, not always clearly visible.

Interior spines are present, even common in some of the specimens. They generally are of large di-

ameter with large openings but they do not extend far along the inner valve surface.

The shell walls of *Taphroestria* are moderately thick but are strengthened in certain parts by the development of cystose shell. Broad flat cysts are laid down under the muscle field but the cysts, formed to strengthen the hood, are generally small and rounded.

The exterior of the brachial valve is so coarsely papillose, or even spinose, that these valves can usually be distinguished from those of *Cyclacantharia*, which also occurs in these beds associated with *Taphroestria*. The brachial valve is short-necked and has narrow, sloping shoulders and is thus quite unlike that of the preceding genera. In profile it is generally slightly convex.

The cardinal process is short but is fairly erect and has large myophores. The shaft is double, so that the process appears to consist of two parts closely pressed together. Anterior to it the shell is nearly smooth, having been covered by adventitious shell and considerably thickened. Anterior to this part may be seen a remnant of the double median ridge which in many specimens divides the adductor scars.

The muscle field is well defined and the four scars of the adductors are usually clear, even in somewhat waterworn specimens. In other specimens the scars are greatly thickened and elevated. None of the brachial valves in the collection shows well-formed endospines. These usually appear as elevated lines or dashes, a few along the front margin. This condition suggests that the spines became reduced as the protective spines over the aperture became more highly developed.

One brachial valve of *T. peculiaris* shows the trace of the brachial ridges, a rare feature in any of these genera. These ridges are elongate, oblique, extending anterolaterally from the muscle field and nearly to the rounded anterolateral shell extremities.

GROWTH.—Few young specimens were obtained, but these indicate a manner of growth similar to that of the other richthofeniacean genera. Specimen USNM 151760k is the youngest measured specimen that has attained a width of aperture of 12 mm, yet it has no trace of the spines on anterior side. The hood is well formed, however, and has attained a length of about 3 mm, while the body chamber is extremely shallow.



*Taphrosestria expansa*, new species

PLATE 303: FIGURES 12-33

Large for genus, squat conical form, widely expanded margin of aperture. Anterior side somewhat less expanded than posterior side; apex flattened and fairly broad, cystose shell sparsely developed, strongest on posterior side and in apical region. Aperture widely flaring, with broad smooth inner surface; cone-in-cone effect moderately developed. Protective spines long, frequently intergrown, flattened but leaving broad and large posterior

channel. Rhizoid spines numerous, fairly stout.

Pedicle valve interior with thick aulacotermia having median elevation on anterior side; muscle area thick and flabellate, muscle scars strongly impressed, not readily differentiated.

Brachial valve nearly flat, distantly and coarsely papillose and spinose; spines short and stout; neck short; reentrant slight; interior with short bilobed cardinal process; brevisseptum almost obsolete; adductor field thickened, brachial ridges not developed.

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thick- ness	aperture length	aperture width
USNM 724b									
152688a	20.6	?	26.0	?	24.0	12.2	?	10.6	15.5
152688b	30.0	11.6	25.0?	6.4	36.6	18.7?	?	11.2	17.5
152688c	24.3	?	23.0	?	29.6	17.3	9.7?	10.8	19.0?
152688d	28.7	?	30.0?	?	27.0	19.0	?	10.5	17.6
152688e	31.0	?	33.0?	?	34.0	20.0	?	10.0	16.9
152688f	23.2	?	30.0	6.5	36.6	17.0	?	10.0	16.0
152688h (holotype)	25.4	11.4	27.0	5.0	25.0	23.2	c.8.0	9.6	22.0

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 721y, 724b.

DIAGNOSIS.—Large *Taphrosestria* with widely expanded and flaring aperture.

TYPES.—Holotype: USNM 152688h. Figured paratypes: USNM 152688b, d-f; 154084. Measured paratypes: USNM 152688a-f. Unfigured paratypes: USNM 152688a, c, g.

COMPARISON.—The large size and widely flaring aperture of this species is a ready distinction from *T. peculiaris*, new species.

DISCUSSION.—This species is uncommon but very distinctive. Except rarely, the spines do not grow so solidly together, as in the smaller species, and they are generally less massive in *T. expansa* than in *T. peculiaris*. *Taphrosestria expansa* usually has a very ragged appearance because of the mode of formation of the flaring aperture. New margins or lips are added at different growth stages, and the earlier ones are usually not covered. In one specimen the flaring lip was built over the spines in such a way that a large expanse of these spines appears

between the old and the new lip. The younger spines are thicker than the older ones.

The dorsal valve is small relative to the great expansion of the aperture. The cardinal process in this species is small and low, aulostegid in expression, and posterodorsally covered by a chilidium.

*Taphrosestria peculiaris*, new species

PLATE 303: FIGURES 1-10; PLATE 304: FIGURES 1-45; PLATE 305: FIGURES 1-20

Small, usually squat cones with strongly rugose exterior and small base of attachment. Anterior side generally slightly lower than opposite one. Posterior side generally flattened. Apical angle broad and generally rounded. Cystose material sparsely developed. Aperture irregular, usually with widely flaring margin, successive apertural margins having strong "cone-in-cone" effect producing elaborately frilled exterior. Protective spines broad and flattened, anastomosing and spreading nearly across aperture to leave narrow channel on posterior side. Rhizoid spines numerous, rounded and fairly stout.

Pedicle valve interior with broad aulacotermia, thickest posteriorly; muscle area broadly flabellate, with poorly to well developed median myophragm; diductor attachments subtriangular, elevated, and excavated below; commonly elevated above adductors; adductor field broad, widely and longitudinally elliptical in outline; interarea well developed; pseudodeltidial region short, occasionally with slight growth track; interior spines short, numerous, and with wide diameter.

Brachial valve slightly convex to flat, strongly and coarsely papillose to spinose. Neck short, reentrant slight; shoulders not well developed; sides narrowly rounded.

Brachial valve interior with erect short-shafted, bilobed cardinal process with large myophores. Brevisseptum short and inconspicuous; median ridge double but obscure; adductor scars thickened in some specimens; brachial ridges usually not clear but directed anterolaterally.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thick- ness	aperture length	aperture width
USNM 710u									
151760a	14.2	?	13.0	?	16.4	15.0	?	15.0	18.4
151760b	14.3	10.5	27.0	?	17.3	21.9	11.8	16.6	26.8
151760c	13.0	10.0?	25.0	4.0	12.4	20.5	9.8	10.0	16.0
151760d	10.4	?	17.0	?	12.8	14.4	?	18.8	20.4
151760e	10.2	8.0?	14.0	?	14.3	14.4	7.0?	14.2	17.5
151760f	12.5	9.0?	20.0	?	18.3	17.0	8.0?	15.4	19.7
151760g	10.7	8.0?	11.0	?	16.7	12.9	7.0?	17.8	22.5
151760h	10.3	?	11.0	?	15.6	14.2	?	16.0	18.0
151760i	12.6	?	10.0?	?	15.6	12.6	4.5?	14.8	18.0
151760j	10.0	7.0	5.0	3.3	13.3	6.8	4.7?	12.8	16.5
151760k	8.0	6.5	7.0	3.0	9.6	5.9	2.3	9.2	12.3
151760l	10.6	?	6.5	?	11.0	11.0	4.7?	15.5	17.0
151760m	10.5	6.5?	13.0?	?	13.8	15.5	7.0?	20.2	22.4
151760n	10.6	8.0	17.0	4.0	12.0	14.2	8.0?	15.4	14.0
USNM 721y									
154082a	16.5	?	20.0	?	16.6	18.2	10.0?	16.5	30.0
(holotype)									

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 707e, 709c, 710u, 716z, 721j, 721t, 721w, 721x, 721y, 722f, 723x, 724a, 724b.

DIAGNOSIS.—Squat, squamose, and rugose, with body chamber occupying about half the height and thick muscle platform in pedicle valve.

TYPES.—Holotype: USNM 154082a. Figured paratypes: USNM 151757a-d; 151759c-f; 151760a, d, f-i, m-q; 154082b; 154085; 154086; 154087; 154109. Measured paratypes: USNM 151760a-n. Unfigured paratypes: USNM 151759a, b; 151760b, e, j-l.

COMPARISON.—This species bears some resemblance to *Teguliferina compacta*, new species, which is a thick-shelled, stout form differing from *Taphroestria*, in having a more cylindrical cup, fewer spines covering the aperture, and a strong

cone-in-cone effect. This species differs from *Taphroestria expansa* in having a smaller size and less flaring cone.

DISCUSSION.—The anastomosing nature of the protective spines and their complete spanning of the cup aperture is a unique development in these peculiar brachiopods. Although the spines cover the cup, a strong gap is left by the shallow trough in the lip of the posterior side. The development is thus intermediate between the conditions seen in *Cyclacantharia* and *Sestropoma*.

#### *Taphroestria?* species

PLATE 303: FIGURE 11

Two specimens from USNM 702-low are unlike any other richthofeniids in the collection. They are

extremely low and squat in appearance, having a very broad base and wide apical angle. The specimens measure 7 and 10 mm, respectively, in height and are almost circular, with a diameter of 31 mm. The margin is strongly flaring especially on the posterior side. The muscle pit is deep, and adductor and diductor scars lateral to the former are readily distinguishable. The brachial valve and protective spines, if any, are unknown. The specimens are assigned to *Taphrosestria* because of the shallow cups, the lack of a septum, and the deep muscle pit.

Figured specimen: USNM 154083a.

### Genus *Sestropoma* Cooper and Grant, 1969

*Sestropoma* Cooper and Grant, 1969:8.

Conical outline, cones varying from short to elongate, tapering to squat, aperture wide, hood elevated and covered by high-crowned, strongly convex net of modified protective spines. Vestibule shallow. Exterior concentrically wrinkled, strong rugose zone near aperture; apex moderately to strongly thickened by cystose shell, depending on growth habit. Rhizoid spines numerous and stout.

Pedicle valve interior with stout aulacotermia and moderately strong longitudinal ridges defining pseudodeltidial region, open to interior throughout length of cone. Muscle mound carinate, elongate, and strongly elevated. Internal spines not strongly developed.

Brachial valve generally flat to slightly convex; interior with reduced and low cardinal process; adductor scars moderately thickened; endospines reduced, in several rows, earlier ones remaining as scattered nodes. Lateral ridges moderately strong.

TYPE-SPECIES.—*Sestropoma cribriferum* Cooper and Grant (1969, pl. 2: figs. 19–21).

DIAGNOSIS.—Like *Hercosestria* externally, but with highly arched coscinidium and thickened muscle mound, without a median septum.

COMPARISON.—This genus is closest to *Coscina*, from the Permian of Sicily, and to *Hercosestria*, from the Leonardian of the Glass Mountains, each of which possesses a sievelike cover over the aperture of the pedicle valve. It is unlike *Coscina* in the form of the cone, but more particularly in not having the myocoelidium characteristic of Old World richthofeniids.

*Sestropoma* is more elongate than *Hercosestria* of

the Glass Mountains in the form of the cup, and differs also in the nature of the network over the cup and the interior. The coscinidium of *Sestropoma* is more even and regular than that of *Hercosestria* and is generally much more elevated and rounded; that of the Leonardian genus is flattened and not usually extended beyond the cup margin. Internally the two genera are also unlike, the Guadalupe Mountain genus having a moundlike muscle area with keeled summit but the Glass Mountains genus provided with a high bladeliike septum.

DISCUSSION.—It is not necessary to discuss in detail all the anatomical features of this genus because some of them are exactly like those of other Richthofeniacea. The pseudodeltidial arrangement and the anchoring of the shell is exactly like that of the other genera. It may be profitable to discuss the net over the cup, the muscle region, and the little that is known about the brachial valve.

Aside from the muscle region, the most distinctive feature of *Sestropoma* is the sievelike network, the coscinidium, overlying the aperture of the pedicle valve. This resembles that of *Hercosestria* but is much more regular. It is difficult to detect the originating spines, which have completely lost their identity, around the margin. Generally the coscinidium is strongly but unevenly arched. In lateral view the sieve is gently convex nearly to its crest and then is narrowly folded to join the hood margin. This makes for a long anterior side but a short posterior side to the coscinidium. In *S. cribriferum* the mesh forms numerous polygonal openings about 1 mm or slightly more in their widest dimension. These do not have a definite shape and vary from elliptical to definitely pentagonal, but the inner margins are all rounded. The coscinidium is about .75 mm thick and is consequently a delicate structure, especially in the silicified state.

In dorsad growth of the hood, as the shell grows and expands, the hood is plastered against the outer posterior wall of the sieve. In broken specimens, the interior wall of the hood has the partially buried remnants of the sieve welded to it, making generic identification possible even when the coscinidium is destroyed.

The mound forming the site of the muscle region is similar to that of *Cyclacantharia* and it is believed that *Sestropoma* was derived from *Cyclacantharia*

by formation of the coscinidium. The muscle mound is greatly elongated and is formed of closely spaced large cysts. The crest of the mound is carinate and in some is almost septate, but a bladeliike septum uniting with the inner surface of the pseudodeltidium is never formed. The sloping face of the mound has two sets of muscle scars, a larger set occupying most of the sloping face and a smaller one occupying the margin of the carina. Muscle marks at the base of the mound are not clearly visible, consequently interpretation of the scars that are visible is difficult. The ones on the long slope may be the diductors or they may be the larger adductors. It is also probable in either case that the elongate muscles on the carinate crest are scars of adductors.

The brachial valve of both species of *Sestropoma* is very delicate; few specimens have been obtained and none of these is complete or perfectly preserved. The cardinal process, wherever it could be seen, seems to be somewhat aborted. In one valve, it is confined almost to the myophore lobes, and in others the myophore is not conspicuous and the shafts are reduced to mere lines. The lateral ridges are indifferently developed but the adductor field seems to be somewhat more strongly thickened than is usual in other genera of this family. The individual scars, however, have not been satisfactorily determined nor were they seen to be dendritic. They are sufficiently thick to be separated into left and right pairs by a fairly deep groove rather than by the low ridge that is more usual among the Productidina. Endospines are clearly seen in only one specimen and these appear in two rows at the anterior. Posterior to the spine rows are scattered nodes, regarded as incompletely resorbed spines left behind in the anterior growth of the shell.

### *Sestropoma cribriferum* Cooper and Grant

PLATE 306: FIGURES 36–51; PLATE 307: FIGURES 1–33; PLATE 308: FIGURES 10–21; PLATE 476: FIGURES 19–26

*Prorichthofenia* sp. Newell et al., 1953, pl. 21: fig. 33, pl. 27: fig. 1.

*Sestropoma cribriferum* Cooper and Grant, 1969:8, pl. 2: figs. 19–21.

Variably elongated cones with apical angle averaging 47° but varying between 29° and 76°. Cross section at aulacoterma generally elliptical, posterior side moderately to strongly flattened. Posterior side flattened but anterior side well

rounded. Sides narrowly rounded. Aperture not flaring, posterior side of hood commonly higher than anterior side. Protective coscinidium forming fairly regular mesh, narrowly rounded medially or toward posterior side, strongly elevated and set deep within aperture, margin of aperture forming rim around net. Rhizoid spines stout.

Pedicle valve with strong aulacoterma but with few interior spines usually located in apical or ventral two-thirds of cone. Pseudodeltidial region open to interior or partly covered apically. Muscle mound narrow, median keel sharp and long, extending from apex dorsally to beyond middle of body chamber. Shell thickest at muscle mound. Muscle marks obscure, apparently confined to muscle mound.

Brachial valve thin and delicate, nearly flat, inside with moderately thickened lateral ridges. Hinge wide but neck generally short. Adductor scars moderately thickened, separated by groove rather than median ridge. Cardinal process consisting of two elongated and disconnected lobes. Endospines few, anteriorly arranged. Partly resorbed endospines posterior to marginal row appearing as scattered nodes.

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member), Bell Canyon Formation (Hegler, Pinery, Rader and Lamar members), Capitan Formation.

LOCALITIES.—Getaway: AMNH 512. Hegler: AMNH 635; USNM 731, 740c, 740d, 732a. Pinery: AMNH 397, 398, 435, 437, 524, 528, 537; USNM 725h, 725n, 733, 736. Rader: AMNH 403, 404, 410; USNM 725f, 725g, 725o, 740a, 740i, 740j. Lamar: AMNH 37, 38, 39, 40, 373; USNM; 725e, 728i, 728p, 728q, 738b. Capitan: USNM 748a.

DIAGNOSIS.—Variable *Sestropoma* with strongly convex, finely meshed coscinidium inset into the cup below the margin.

TYPES.—Holotype: 151656b. Figured paratypes: USNM 151656a, c, f, h-k. Unfigured paratypes: USNM 151656d, e, g. Figured hypotypes: USNM 151656l, m; 151665; 154079a; 154080a-d, g, k, l; 154583a-d. Measured paratypes: USNM 151656a, c-i. Measured hypotypes: USNM 151670a-e; 151676a; 151678a; 154080a, c, d; 154583a.

COMPARISON.—This species is smaller and has a finer meshed coscinidium than *S. mexicana*, new species, the only other species of the genus now known.



## MEASUREMENTS (in mm).—

	<i>apical angle</i>	<i>length</i>	<i>brachial valve length</i>	<i>brachial valve width</i>	<i>surface length</i>	<i>hinge width</i>	<i>midwidth</i>	<i>height</i>	<i>thick- ness</i>	<i>aperture length</i>	<i>aperture width</i>
AMNH 410											
151670a	76°	25.4	14.5	27.8	31.0	8.5	35.3	40.0	22.8	29.2	40.0
151670b	54°	25.2	17.3	24.5	45.0	7.3	29.7	39.0	21.4	26.4	34.2
151670c	53°	18.8	14.0	22.0	33.0?	9.0	25.5	33.3?	22.0	22.0	31.4
151670d	42°	18.8	13.3	18.5	24.0	6.3	23.0	23.8	18.5	19.7	24.3?
151670e	57°	14.8	10.0	15.0?	18.0	5.0	18.8	18.1	11.0	19.4	20.0
AMNH 403											
151678a	62°	20.7	13.5	24.8	37.0	8.2	28.8	27+	23.2	21.4	35.0
AMNH 39											
151676a	52°	19.9	16.0	25.3	34.0?	7.3	26.9	27.3+	22.0	22.3	30.8
USNM 731											
151656a	34°	19.0	16.0?	18.0?	38.0	?	21.4	42.0	27.0?	21.4	25.4
151656b	33°	17.2	12.0?	18.0?	30.0	?	19.0	37.0	25.0	25.9	23.9
(holotype)											
151656c	26°	15.3	12.0?	14.0?	32.0	?	15.5	32.8	?	17.0	16.5
151656d	29°	11.5	8.0	12.0	16.0	4.5	15.9	22.0?	12.3	13.0	17.0
151656e	33°	10.2	8.0	10.0?	16.0	?	12.4	17.7	?	8.7	14.0
151656f	31°	8.0	7.0?	9.0?	14.0	?	9.0	16.3	?	10.2	12.3
151656g	54°	8.0	7.0	8.5	10.0	2.0	9.6	8.1	6.0	9.3	12.0
151656h	36°	15.9	9.5	15.0	12.0	4.3	18.4	21.0	15.6	19.8	19.9
151656i	29°	11.3	11.0?	12.5?	18+	?	13.0	23+	?	13.4	16.0
USNM 725f											
154080a	44°	15.0	?	?	20.0?	?	14.8	26.2	?	15.0	17.6
154080c	63°	19.0	?	?	32.0?	?	25.5	34.0	?	19.3	24.4
154080d	44°	16.8	?	?	25.0?	?	16.3	28.2	?	18.4	18.3
USNM 740j											
154583a	53°	20.0	14.0?	20.0?	42.0?	8.6	25.5	38.0+	23.0?	22.8	25.5

DISCUSSION.—Specimens of this genus are not common in the Bell Canyon Formation, consequently the collection is not large enough to permit analysis of the variation seen in the specimens we have. We have not seen such large clusters of shells as those of other richthofeniaceans that occur in the Glass Mountains, so we are unable to evaluate the variation due to crowding. The species seems to have lived in small clusters of a few specimens rather than in patch reefs. The variation occurs in the form of the cup and in the coscinidium. Long slender forms of the species, such as the type specimen, occur in the lower part of the Bell Canyon Formation in the Hegler Member. Some short forms are also found. In the upper part of the Bell Canyon the specimens tend to be larger and wider, but here, too, slender forms are found. It seems best to

recognize only the one species until more can be discovered about the limits of variation.

Growth series are not present in detail but some young individuals are preserved. Unfortunately, it is not possible to state exactly at what size the coscinidium was formed. Specimens less than 7 mm in height appear not to have a sieve but do have a ring of incipient spines. Specimens with a height of 10 mm appear to have a sieve. One specimen 8 mm high has no trace of the coscinidium, nor are the incipient spines in evidence. Another specimen (USNM 152694) about 20 mm high has an incomplete coscinidium which suggests how it originated. The spines on the anterior side have lateral branches, but most of these have not yet joined their fellows. On the posterior side the spines are flattened and completely interconnected. The me-

dian region is open; presumably continued growth would have closed it.

*Sestropoma mexicanum*, new species

PLATE 284: FIGURES 31-33

Large, conical, apical angle of 75°; dorsal side conspicuously flattened, sides narrowly rounded; apex bent slightly in dorsad direction. Marginal lip long; coscinidium strongly convex with apex about midway, strongly elevated above marginal lip of aperture and with coarse pores. Dorsal valve unknown.

MEASUREMENTS (in mm).—From locality USNM 815, specimen 153675 (holotype): length 22.5, width 29.0, thickness 19.0?, height 41.7, aperture length 31.8, aperture width 40.5.

STRATIGRAPHIC OCCURRENCE.—Guadalupian (*Wagenoceras* Zone).

LOCALITY.—USNM 815 (= AMNH 1028).

DIAGNOSIS.—Large wide *Sestropoma* with narrowly domed coscinidium having the crest at about mid-aperture.

TYPES.—Holotype: USNM 153675.

COMPARISON.—This is a wider, stouter, and larger species than that of the Bell Canyon Formation, and the coscinidium has its crest at midvalve rather than near the dorsal side, as in *S. cribriferum*.

Genus *Collumatus* Cooper and Grant, 1969

*Collumatus* Cooper and Grant, 1969:6.

Small, squat cups attached directly to substrate but often with expanded base of attachment; no attachment spines; aperture elliptical to round depending on attachment, covered by lacy network (coscinidium) as in *Hercosestria* but with open channel on posterior side. Sides smooth, without any ornament.

Pedicle valve interior with narrow ridge (aulacotermia) around inside on which brachial valve rests. Hinge narrow; sockets small, defined by narrow shelf on each side of hinge area; posterior edge of brachial valve inserted in narrow groove in posterior wall of pedicle valve; muscle scars on valve floor; diductors somewhat flabellate; anterior side marked by low, wide ridge.

Brachial valve interior with narrow hinge; cardinal process bilobed and with large bilobed myophore; myophore posteriorly partially covered by narrow convex chilidium. "Tooth" small. No myophragm. Adductors scars thickened; no endospines.

TYPE-SPECIES.—*Collumatus solitarius* Cooper and Grant (1969:6, pl. 1: figs. 22-26).

COMPARISON.—This genus need be compared only with those having a network over the aperture, i. e., *Hercosestria*, *Coscinarina*, and *Sestropoma*. *Collumatus* differs from all these in being cemented directly, and by a large surface, to the substrate, completely devoid of spines. It has no septum like that of *Hercosestria* and does not develop a thickened muscle area like that of *Sestropoma*. *Coscinarina* from Sicily has a myocoelidium, a structure not yet seen in adult richthofeniids in North America. The growth form is unlike that of the other genera except *Hercosestria* which has a similar, squat form.

DISCUSSION.—The unique features of this genus are its growth form and its method of cementation, leading to a solitary habit; its complete lack of anchor spines; and the absence of endospines on the inside of the brachial valve. The known richthofeniaceans are colonial in habit, usually forming small clusters, masses or perhaps patch reefs. The individuals are initially cemented at the apex, usually a small point, and braced by struts in the form of rhizoid or cementing spines. In contrast, *Collumatus* cements by a broad surface to shells and other parts of the substrate. Only individuals have been found, and the form of the cicatrix indicates that it had no connection with any other individual by cementation. One specimen occupies the interior surface of a small *Neospirifer* brachial valve. Others have elliptical cicatrices, indicating attachment to a thick bryozoan branch or other round object, such as a crinoid stem. One is attached to the convex surface of a small *Enteleles*, another to *Meekella*. Every specimen appears to have had a solitary existence.

No spines were seen on any of the specimens. Cementation and strengthening of the cup seems to have taken place by deposition of successive smooth sheets, one draped over another. These act instead of spines and may be a specialized attachment arrangement corresponding to the spines of other richthofeniaceans.

The hingement of the valves is like that of other genera of the Richthofeniacea. In *Collumatus* there is a more strongly developed notch in the posterior wall for the movement of the brachial valve. No specimen shows any trace of a myophragm in the pedicle valve and the brachial valve appears to have lost completely the endopsines so characteristic of *Hercosia* and *Cyclacantharia*.

### *Collumatus solitarius* Cooper and Grant

PLATE 89: FIGURES 24–30; PLATE 92: FIGURES 1–25; PLATE 305: FIGURES 21–53; PLATE 306: FIGURES 1–35; PLATE 309: FIGURES 16–29

*Collumatus solitarius* Cooper and Grant, 1969:6, pl. 1: figs. 22–26.

Small, solid, crater-like shells with expanding base and broad, irregular attachment surface. Aperture narrower than base and covered by coscinidium with elliptical opening along posterior margin of pedicle valve. Sides smooth, formed by draped sheets of shell substance; aperture margin thickened and rounded. Surface without ornament and without attachment spines.

Pedicle valve as above but with moderately thickened aulacotermia, strongest on anterior side. Brachial valve gently convex, narrowly elliptical in outline, with narrowly rounded sides, and with anterior margin slightly indented medially. Surface smooth.

Interior as defined for genus.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	width	brachial valve width	hinge width	aperture length	aperture width
USNM 732j							
153043a	13.3	7.3	15.0	10.0	4.0	5.0	10.5
153043b	23.5	9.6	23.7	16.2	5.2	10.6	16.4
153043c	17.3	8.8	21.6	13.6	?	8.2	14.1
153043d	17.8	8.5	25.0	11.9	4.2	7.6	12.0
153548a (holotype)	11.0	c. 7.5	12.4	c. 10.4	?	10.0	9.0

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 700v, 732j, 736x, 737y.

DIAGNOSIS.—Richthofeniacea having a solitary habit and anchored by broad cementation rather than by spines.

TYPES.—Holotype: USNM 153548a. Figured paratypes: USNM 153548b-d, f, g. Figured hypotypes: USNM 153043a-d, f, g, o, p; 154088a-j; 154089a-d; 154090; 154114a, b; 154526a-c. Measured hypotypes: USNM 153043a-d. Unfigured paratype: USNM 153548e.

COMPARISON.—No other species of the genus is known.

DISCUSSION.—Nearly all specimens of this species in the collection had been ripped off their moorings and were found in a shell breccia. Inasmuch as the attachment scars are large, the specimens may have been torn loose during a violent storm. It is not known just what niche *C. solitarius* may have occupied but it must have been in sheltered spots on

the bottom among broken shells and other debris.

### Family RICHTHOFENIIDAE Waagen, 1885

Richthofeniacea having a myocoelidium in the pedicle valve.

### Genus *Richthofenia* Kayser, 1881

*Richthofenia* Kayser, 1881:352; 1883:74, 195.

#### *Richthofenia* species

PLATE 200: FIGURES 35–41

Specimens of this genus are figured for comparison with members of the Hercosiinae and Cyclacanthariinae. Neither of these has a myocoelidium for lodgement of the muscles. The specimens illustrated from the Salt Range, Pakistan, have an unusually large development of cystose shell in the pedicle valve.

Figured specimens: USNM 154051a-c, f.

## Subfamily PRORICHTHOFENIINAE

Muir-Wood and Cooper, 1960

Full characteristics of the subfamily uncertain. As explained in detail in the discussion of *Cyclacantharia*, the genus *Prorichthofenia*, which is based on *Crania permiana* Shumard, is at present an uncertain concept. Shumard's specimens, now lost, came from the "White Limestone" of the Guadalupe Mountains. Girty (1909) attempted to interpret Shumard's species but based his views on specimens from rocks much older in the Glass Mountains than the "White Limestone" (= Capitán-Carlsbad Formations). As a basis for his genus *Prorichthofenia*, R. E. King (1931) chose his own interpretation of Girty's conception of *Crania permiana*. The White Limestone contains two genera of richthofeniids, but which one Shumard had, or whether he had both of them or neither, will probably never be known. We have felt it best therefore to leave *Prorichthofenia* in a nebulous state.

## Superfamily PRODUCTACEA Gray, 1840

## Family OVERTONIIDAE

Muir-Wood and Cooper, 1960

Productacea with brachial ridges oblique; sessile bilobed cardinal process, each lobe posteriorly incised, rarely with minute median lobe; cardinal process supported by septum; exterior spinose, rugose, or lamellose, rarely anteriorly costate.

## Subfamily OVERTONIINAE

Muir-Wood and Cooper, 1960

Overtoniidae with exterior spinose, rugose, or lamellose, rarely anteriorly costate.

Genera in West Texas: *Fimbrinia* Cooper, 1972; *Simplicarina*, new genus; *Rhytisia*, new genus.

The members of this subfamily are rare and obscure shells, mostly small and fairly restricted. *Fimbrinia* is found in the Sierra Diablo and the Glass Mountains but the other two are only known from the Glass Mountains.

Genus *Fimbrinia* Cooper, 1972

*Fimbriaria* Muir-Wood and Cooper (not Froelich, 1802), 1960:186.

*Fimbrinia* Cooper, 1972:450.

Small, suboval, hinge generally narrower than midwidth. Cardinal extremities obtuse, without spines; valves deeply concavoconvex. Valves ornamented by broad concentric bands, each bearing row of stout spines. Brachial valve with more slender spines and rows of dimples.

Pedicle valve interior without adductor ridge but with ear deflected ventrally, with low baffle.

Brachial valve interior with divided posterior platform, widely bilobed cardinal process in ventral and dorsal views. Adductor scars on anteriorly elevated platform with posteriorly attenuated ends also elevated. Brevisseptum short, not reaching mid-valve and terminating at anterior end of adductors. Brachial ridges directed anterolaterally. Endospines numerous, long and stout.

TYPE-SPECIES.—*Overtonia plummeri* R. H. King (1938, p. 276, pl. 39: figs. 19–22).

DISCUSSION.—This is a rare genus in Pennsylvanian and Permian rocks of the United States; consequently, any interior features revealed are of interest. Specimens from the Sierra Diablo exhibit details of the brachial valve interior.

Interior characteristics of the pedicle valve are still uncertain, because all the specimens recovered from the Sierra Diablo are thin and delicate. These fail to reveal the muscle scars but show clearly that the adductors were not attached to a ridge, as in many genera. The beak is strongly incurved and hangs over the hinge. Ears are not well-developed but are deflected toward the ventral valve. Some specimens have on their inside a low and narrow baffle that runs just inside the hinge to the ear, then just under the outer margin of the ear to disappear on the lateral slope.

Chief interest in the interior details centers about the cardinal process and the adductor platform. The cardinal process is attached to a fairly well developed posterior platform. It is bilobed in ventral and dorsal views and a median lobe is not developed in the largest specimens in the collection from the Sierra Diablo. The cardinal process thus maintains a productellid appearance in the species thus far studied.

The adductor scars are located on thick teardrop-



shaped callosities that are strongly excavated anteriorly. At the posterior end of these callosities a narrowly-looped ridge surrounds the attenuate end, the two forming a short but deep trough lying on the posterior platform that forms the floor of the depression. The outside of the loops unite with the brachial ridges. The brevisseptum is very short and scarcely extends anterior to the muscle platform. At its anterior end, it is bladelike and strongly elevated but terminates abruptly and does not reach midvalve. The anterior slope, which occupies about two-thirds the valve length, is marked by scattered, thick, sharply pointed endospines.

The exterior of *Fimbrinia* is distinctive among Permian productids because of its regularity and some unusual details. Both valves are characterized by a single row of spines occupying the middle of each lamella. The lamellae are elevated into crests at the spines and then continue anteriorly nearly flat or slightly concave almost to the next anterior row of spines. Since each newly formed lamella originates on the inside just anterior to the row of spines, the anterior half of the posterior lamella overlaps the posterior half of the next anterior lamella. In most specimens these thin and delicate lamellae are commonly broken off or are raggedly preserved. When complete, they terminate near the place of origin of the spine row, and, in some instances, their distal margin lies on the spines. A similar condition exists in the brachial valve, where the anterior, free part of the lamella often lies over the base of the spines of the next row forward. Deep dimples, probably corresponding to the spines of the pedicle valve; appear in rows on the posterior part of the lamellae of the brachial valve.

**STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION.**—Because of its great rarity, little is known about the distribution of this genus in time and space. It appears in the Wolfcampian of Bolivia where Kozłowski (1914) described *Productus cristatotuberculatus*. King (1931:82) listed Kozłowski's species in the *Uddenites*-bearing Shale Member fauna. The type-species of *Fimbrinia* occurs in the same zone in north central Texas (lower Cisco) and in several other formations higher in the Pennsylvanian. Stehli (1954:326) identified the type species in the lower part of the Bone Spring Formation in the Sierra Diablo.

In the Glass Mountains we have found the genus

in the *Uddenites*-bearing Shale Member and in the overlying Neal Ranch and Lenox Hills formations where it is very rare. The youngest occurrence of the genus in the Glass Mountains is in the basal Skinner Ranch Formation (equivalent of the Decie Ranch Member) which corresponds to Stehli's discovery in the Bone Spring of the Sierra Diablo. This seems to be the final appearance of the genus.

### *Fimbrinia ovata*, new species

PLATE 310: FIGURES 1-31

*Overtonia plummeri* Stehli (not R. H. King), 1954:327, pl. 23: figs. 5-7.

Moderately large for genus, elongate oval to subtriangular in outline; hinge narrower than midwidth; sides and anterior well rounded. Cardinal extremities obtuse. Surface marked by concentric bands bearing single row of moderately long, anteriorly curved spines, about 12 rows anterior to umbonal region in large adults. Brachial valve similarly marked but concentric bands bearing large dimples as well as spines more slender than those of pedicle valve.

Pedicle valve with strongly convex lateral profile, umbonal region narrowly rounded but middle and anterior regions less so. Anterior profile narrowly convex, sides steeply sloping. Beak strongly incurved, umbonal region protruding considerably posterior to hinge. Median region narrowly swollen, swelling continuing anteriorly to form slight ventral fold in anterior margin. Umbonal slopes precipitate; lateral slopes steeply sloping.

Brachial valve slightly wider than long, deeply concave in median region. Sides and anterior sloping medially fairly evenly; anterior margin slightly and narrowly sulcate to accommodate ventral fold of pedicle valve anterior.

Pedicle valve interior with moderately developed baffle across ears.

Brachial valve interior with small bilobed cardinal process on prominent and somewhat elevated posterior platform. Adductor scars on anteriorly elevated and excavated callosities with narrowly looped ridges anterior to cardinal process. Brevisseptum anteriorly strongly elevated but short. Anterior slopes strongly endospinose but endospines stout and scattered. Brachial ridges poorly developed.

MEASUREMENTS (in mm).—Thickness unmeasurable.

	length	brach- ial valve length	sur- face length	hinge width	mid- width	height
USNM 728f						
152701a	13.4	10.0	19.0?	7.7	11.7	7.8
(holotype)						
152701b	10.8	8.1	18.0	6.9	10.5	5.8
152701c	10.2	7.9	17.0	7.3	9.7	5.5?
152701d	9.4	7.8	15.5	5.7	8.6	5.0
152701e	7.7	6.7	13.0	4.8*	7.8*	4.3
152701f	7.0	6.3	9.0?	6.4	7.1	3.2
152701g	4.6	4.2	?	3.9	4.6	1.9
152701h	9.7	7.9	?	8.3	10.7	6.1
152701i	?	7.8	?	7.2	9.5	?
152701j	?	9.0	?	9.1	11.7	?

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation (lower), Skinner Ranch Formation (lower).

LOCALITIES.—Bone Spring: AMNH 628, 696; USNM 725c, 728e, 728f, 728h. Skinner Ranch: USNM 705a, 720e, 724q.

DIAGNOSIS.—Coarsely lamellose *Fimbrinia* with narrow hinge in the adult.

TYPES.—Holotype: USNM 152701a. Figured paratypes: USNM 152701i-m; 153873; 153874a-c. Measured paratypes: USNM 152701b-j. Unfigured paratypes: USNM 152701b-h.

COMPARISONS.—The ornament and size of this species are like those of *F. plummeri* (R. H. King) of the late Pennsylvanian or early Permian, but the main difference is the much narrower hinge of the Sierra Diablo species. Fairly young specimens are like *F. plummeri* in having the hinge slightly narrower than the midwidth, but in the adult the hinge is much narrower, creating an almost subcarinate condition.

Some differences between the two species appear inside the brachial valve. The cardinal process of *F. ovata* is more delicate, but the adductor platform is more elevated and is excavated anteriorly. The platform of *F. plummeri* is thick but not clearly defined. A thickened marginal rim in *F. plummeri* is absent in the Sierra Diablo species, and the lateral ridges of the Graham Shale species are better defined than those of *F. ovata*.

### *Fimbrinia plummeri* (R. H. King)

PLATE 311: FIGURES 5–14

*Overtonia cristato-tuberculata* R. E. King (not Kozłowski), 1931:82, pl. 20: figs. 1–3.

*Overtonia plummeri* R. H. King, 1938:276, pl. 39: figs. 19–22.  
—Muir-Wood and Cooper, 1960:186, pl. 46: figs. 1–9.

This species was described fully by its author, and its anatomy was later elaborated by Muir-Wood and Cooper, so it seems unnecessary to make further description. Specimens answering fully to the characters of this species were collected and described by R. E. King from the Glass Mountains.

A few specimens of *Fimbrinia* in the silicious residues from beds 9–12 of the Neal Ranch Formation appear to be juveniles. These are wide-hinged and subcircular in outline. The largest specimen measuring 8 mm in length has 20 spines around the margin, the number appearing at the same length in specimens of *F. plummeri* from the Graham Formation. The Wolfcampian specimens are therefore placed tentatively in this species.

TYPES.—Figured specimens: YPM 11499a, b.

STRATIGRAPHIC DISTRIBUTION.—Gaptank Formation (*Uddenites*-bearing Shale Member), Neal Ranch Formation (beds 4–14 of P. B. King).

LOCALITIES.—*Uddenites*: King 88, 94, 94s and Tba. Neal Ranch: USNM 701, 701a<sup>3</sup>, 701d.

### *Fimbrinia* species unidentifiable

PLATE 310: FIGURES 32–34; PLATE 311: FIGURES 1–4

Three lots containing this genus are represented by poorly preserved specimens that cannot be satisfactorily placed in any of the known species.

SPECIES 1.—Six decorticated specimens preserved in conglomerate indicate a species suggesting *F. ovata*, new species. The pedicle valves are elongate-oval and narrow-hinged. The brachial valves appear shallow and are much pitted. The specimens come from the Lenox Hills Formation at USNM 707j and possibly USNM 715.

Figured specimens (Pl. 311: figs. 1–4): USNM 153999a, b.

SPECIES 2.—A small, poorly preserved silicified specimen from USNM 727e has a fairly wide hinge and preserves some of its spines.

Figured specimen (Pl. 310: fig. 32): USNM 153876.

SPECIES 3.—An immature specimen possibly related to *F. ovata* was found at USNM 728–1.

Figured specimen (Pl. 310: figs. 33, 34): USNM 153877.

*Simplicarina*, new genus

[Latin *simplicis* (unmixed)]

Small, deeply concavo-convex, subrectangular, hinge as wide or wider than midwidth; ears small; beak small, not strongly umbonate; anterior margin with modest dorsad fold. Surface smooth; spines few, two on lateral slopes, one or two on trail. No brachial valve spines.

Pedicle valve interior with moderately developed ear baffle; adductor scars large, slightly thickened; diductor scars marked by small, thick endospines.

Brachial valve interior with small elongate, sessile bilobed cardinal process on posterior platform at high angle to posterior margin; ear baffles low, serrated, extended laterally as low submarginal rim forming thickening on anterior side of visceral region. Adductor scars elongate, teardrop-shaped, small; brevisseptum low. Brachial ridges somewhat oblique, not strongly thickened.

TYPE-SPECIES.—*Simplicarina incompta*, new species.

DIAGNOSIS.—Generalized Overtoniinae with few spines.

COMPARISON.—This small genus suggests *Echinauris* but is not provided with the characteristic brush of spines on the ears that is so distinctive of that genus. It also lacks any spines on the brachial valve. *Simplicarina* suggests the Early Mississippian *Geniculifera* Muir-Wood and Cooper in its paucity of spines, but that genus, which also possesses few spines, has them placed differently, mostly on the

trail and posterior margin rather than on the lateral slopes as in *Simplicarina*.

*Simplicarina incompta*, new species

PLATE 310: FIGURES 35–41; PLATE 312: FIGURES 25–50

Small; subrectangular outline, hinge straight, about equal to midwidth; sides slightly oblique and gently rounded; anterior margin broadly rounded with slight median flattening. Body cavity thin. Flanks and umbonal slopes marked by two stout spines; trail with few scattered spines creating obscure costae.

Pedicle valve strongly convex in lateral profile, strongly domed in anterior profile, steep slopes; median region with well-defined sulcus originating in umbonal region; anterior slope gently convex, long, and steep. Umbonal and median regions strongly swollen. Beak small; umbo protruding slightly posterior to posterior margin. Ears small, not protruding, moderately rounded approximately at right angle.

Brachial valve deeply concave, sides and anterior sloping steeply to deepest part at midvalve; ears small, slightly concave.

Pedicle valve interior with small ear baffles and slightly thickened, fairly large adductor field. Brachial valve interior with small, narrow cardinal process, low brevisseptum, elongate adductor field, and faintly thickened brachial ridges. Ear baffles serrated, continuing as submarginal rim around entire visceral region.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	mid- width	hinge width	height	thick- ness
USNM 721j							
151585a	8.0	6.9	15.0	8.3	8.6	4.3	1.3
151584	10.0	8.3	17.0	10.5	8.7	5.8	3.2
USNM 720d							
151583	7.8	6.8	12.0	8.5	8.0	4.4	1.4
USNM 726d							
153927a	11.5	9.5	20.0	12.0	12.5	7.5	3.0
(holotype)							

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation (upper).

LOCALITIES.—USNM 720d, 721j, 721z, 722e, 726d.

DIAGNOSIS.—*Simplicarina* with a wide shallow

sulcus on the pedicle valve.

TYPES.—Holotype: USNM 153927a. Figured paratypes: USNM 151583, 151585a-c. Measured paratypes: USNM 151583, 151584, 151585a.

COMPARISON.—This little shell suggests some species of *Echinauris* but it is less spinose than the members of that genus and has no spines on the brachial valve.

DISCUSSION.—This is a rare species found only in the Road Canyon Formation. On the exterior the development of the sulcus or anteromedian flattening of the pedicle valve appears to be associated with the presence of two spines on the trail. These are moderately spaced and produce a longitudinal costa which helps to define the sulcus. On the inside of the pedicle valve the spines of the exterior penetrate the shell and are defined by fairly long tubes.

### *Rhytisia*, new genus

[Greek *rhytis* (fold)]

Small, subquadrate to subcircular in outline; hinge usually narrower than midwidth; ears small and inconspicuous; beak small; anterior margin undeflected. Surface with umbonal and visceral regions of both valves marked by strong, concentric wrinkles. Halteroid spines strong, few, scattered at random; ears smooth or each occupied by single spine. Brachial valve without spines.

Pedicle valve with delthyrial opening nearly obsolete; ear baffles fairly strong; musculature well preserved with flabellate diductor scars not anteriorly surrounding elongated, teardrop-shaped adductors.

Brachial valve with small cardinal process, bilobed in ventral and posterior views; shaft short, buttressed by low median ridge divided into two at base of shaft but narrowing and becoming one where joining short anteriorly elevated brevisseptum. Endospines small and delicate; brachial ridges obliquely elongated; ear baffles low, oblique ridges; adductor scars, elongated, teardrop-shaped, slightly elevated, median set larger than lateral scars.

TYPE-SPECIES.—*Rhytisia rugosa*, new species.

DIAGNOSIS.—Concentrically wrinkled Overtoniinae with scattered halteroid spines on the pedicle valve but no spines on the brachial valve.

COMPARISON.—This genus has an appearance very similar to that of *Echinauris* and *Simplicarina*. Its strong wrinkles and lack of long, bunched-together halteroid spines on the pedicle valve and the lack of spines on the brachial valve separate it from *Echinauris* and other genera having brachial valve

spines. The more numerous spines and concentric wrinkles are a ready means of separation from *Simplicarina*, which has few spines and a shell with obscure radial ornament.

DISCUSSION.—This is an uncommon shell, so far known only from a few localities in the Road Canyon Formation. It is difficult to identify when occurring with abundant *Echinauris*, whose young it simulates. It is, however, not a young form of another genus because the valves are thick and stout, clearly indicating adult specimens.

The rugosity of the exterior is not uniformly well preserved because some specimens retain it only on the slopes, whereas others have it only on the umbonal region. Well-preserved specimens have the valve wrinkled for more than half the length. Most pedicle valves preserve the wrinkles well, even in specimens in which they are worn or poorly developed on the brachial valve.

We have been unable to determine a fixed pattern for the spines on the pedicle valve. A few specimens have a spine on one ear or the other or on both ears, but they are not common. Well preserved spines are long, often equal to the shell length. The spines are stout and are given off at a fairly high angle, 30° or more. They usually come directly from the shell and are not attached to spine ridges as in *Avonia*, *Krotovia*, and *Levipustula*.

Inside the pedicle valve the delthyrial opening is nearly obsolete and is very small; the ear regions are considerably thickened and flattened and the ear baffles are slightly fluted. The diductor scars are subflabellate and triangular but do not surround the adductor scars anteriorly. The adductor scars are elongated, slightly thickened, and teardrop-shaped and have the same appearance and size as the median adductor scars of the brachial valve. The spine openings inside the pedicle valve are narrowly elliptical and have thickened rims.

The brachial valves are moderately to strongly concave and are variably thickened internally. The cardinal process is small and narrowly bilobed with each lobe having a median incision. The lobes coalesce proximally and form a pointed extension that protrudes slightly beyond the umbo and served as a lophidium. The lateral ridges are short and extend into the low, slightly fluted ear baffles that extend anterolaterally almost to midvalve. The brevisseptum is anteriorly elevated and descends posteriorly to join the median ridge that bolsters



the cardinal process. This ridge divides posteriorly to form a double ridge like that of *Leioproductus*. The median adductor scars are elongate, teardrop-shaped, and commonly slightly thickened. The lateral scars are similarly shaped but smaller. Some specimens have a short ridge extending part way anteriorly between the lateral and median scars. The brachial ridges are well marked in many specimens and are greatly elongated anteriorly, as in the *Overtoniinae*.

*Rhytisia rugosa*, new species

PLATE 311: FIGURES 15-59

Subquadrate to subcircular outline, hinge usually narrower than greatest width at midvalve; sides gently to moderately rounded; anterior margin strongly rounded, Ears small, slightly protuberant, rounded to subangular; anterior commissure with-

out deflection. Surface with posterior half or two-thirds marked by strong, narrowly rounded, fairly regular, concentric wrinkles. Spines all halteroid, stout, fairly long, length often equal to valve length arising at fairly high angle of 30° to 60°, curved anteriorly, and distributed in no discernible pattern. Brachial valve ornamented by wrinkles only, usually confined to posterior half.

Pedicle valve strongly and evenly convex in lateral profile and narrowly and strongly arched in anterior profile; sides very steep. Umbonal region strongly swollen; beak slightly protruding over umbo of opposite valve. Median region inflated; anterior slope steep.

Brachial valve moderately to fairly deeply concave, greatest concavity at midvalve, with steep slopes all around; ears flattened.

Pedicle and brachial valve interiors as defined in generic description.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	mid- width	hinge width	height	thick- ness
USNM 721z							
152703a	8.3	?	15.0	10.0	8.6	4.9	?
152703b	7.7	?	12.0	8.5	8.3	3.7	?
152703c	8.5	7.5	13.5	9.7	6.8	4.3	2.5
(holotype)							
152703d	7.7	?	12.5	7.8	5.2	4.1	?
USNM 724c							
152704a	9.4	?	14.5	10.5	10.0	4.9	?
152704b	8.9	?	14.0	9.9	8.0	4.4	?
152704c	8.4	?	13.0	8.2	6.5	4.4	?
152704d	7.8	?	12.0	8.8	5.8	3.8	?
152704e	6.9	6.0	10.5	7.3	6.4	3.2	1.7
152704f	5.9	5.5	9.0	6.3	4.6	2.8	1.4
152704g	5.7	5.0	8.5	6.7	6.0	3.7	2.1
USNM 721j							
152979a	11.0	8.7?	18.5	11.0	8.3	6.0	?
152979b	8.9	7.5?	16.0	8.0	8.7	5.0	?
152979c	8.3	7.1	13.0	8.6	8.5	4.7	?
152979d	8.5	7.0	12.0	8.3	7.9	4.2	?
152979e	8.2	7.3	13.0	7.7	7.0	4.2	?

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation, Road Canyon Formation.

LOCALITIES.—Cathedral Mountain: USNM 721u. Road Canyon: USNM 706f, 720d, 721j, 721x, 721y, 721z, 722e, 723x, 724c, 726d, 726e, 732j, 736x.

DIAGNOSIS.—Small *Rhytisia* with strongly wrinkled posterior and stout halteroid spines.

TYPES.—Holotype: USNM 152703c. Figured

paratypes: USNM 152703b, e-i, k, l; 152704 b, d, i-k; 152979a, c; 154000a, b. Measured paratypes: USNM 152703a, b, d; 152704a-g; 152979a-e. Unfigured paratypes: USNM 152703a, d, j; 152704a, c, e-h; 152979b.

COMPARISON.—No other species of this genus is known.

DISCUSSION.—Several specimens of this species

have been found with attachment rings on the beak. This suggests that they were attached in youth but lived loose on the sea bottom in later life. The species is variable in respect to convexity, prominence of the umbo, and wrinkling. The shell has a tendency to smooth out the wrinkles in the anterior of the shell.

### Family MARGINIFERIDAE Stehli, 1954

Progressive, small or medium Productacea, usually with a few scattered or symmetrically arranged spines; pedicle valve with or without marginal ridges. Brachial valve interior usually with marginal ridge or anterior rows of endospines; trilobed cardinal process with median lobe bent in a dorsal direction.

#### Subfamily MARGINIFERINAE Stehli, 1954

Marginiferidae having continuous externally geniculated marginal or submarginal ridges around the visceral disc of the brachial valve; adductor scars smooth.

Genera in West Texas: *Hystriculina* Muir-Wood and Cooper, 1960; and *Kozlowskia* Fredericks, 1933.

Members of this family in the Glass Mountains are confined to the Lower Permian, where they are uncommon. These genera are more abundant and characteristic of the Pennsylvanian. Both genera are rare to common in parts of the Wolfcampian, but *Kozlowskia* is believed to extend into the Leonardian.

#### Genus *Kozlowskia* Fredericks, 1933

*Kozlowskia* Fredericks, 1933:29.—Muir-Wood and Cooper, 1960:212.—Williams et al., 1965:H479.

Small, alate marginiferids with strongly convex pedicle valve, moderately concave and geniculated brachial valve. Hinge usually forming widest part. Pedicle valve with sulcus varying in development in different species, usually not strongly developed. Surface costellate to obscurely costate, ribbing tending to obsolescence in some species; visceral disc and ears wrinkled in some species. Spines confined to pedicle valve, variable; in row along posterior margin; curved row at base of lateral slope, with

anteriormost spine large and stout; two or more stout spines on trail; scattered small spines on body of shell. Brachial valve without spines but with anterior and lateral border of overlapping trails.

Pedicle valve interior with elongated and usually thickened adductor platform; ear baffles strong and deeply corrugated on inside surface, extended anteriorly and medially in some species as low submarginal ridge.

Brachial valve interior with small sessile, trilobed cardinal process, usually with only slight development of posterior platform. Lateral ridges variable, but ear baffles strongly developed and continued anteriorly and medially as strong, flattened marginal ridge at edge of visceral disc. Adductor scars usually thickened, forming platform; brevisseptum distally elevated and reaching midvalve; brachial ridges usually well developed, commonly greatly thickened. Endospines few, usually in one or two rows, generally stout, commonly long and rarely greatly elongated.

TYPE-SPECIES.—*Productus capacii* d'Orbigny (1842:50, pl. 3: figs. 24–26).

DIAGNOSIS.—Marginiferidae with large ears, subdued ornament and a band of trails on the brachial valve.

COMPARISONS.—The prominent band of overlapping trails distinguishes this genus from all other members of the Marginiferidae in the Glass Mountains. *Hystriculina* might be confused with *Kozlowskia* because of its similar ornament and general configuration, but the lack of trail bands and greatly extended ears make separation easy.

*Kozlowskia* is most like *Marginifera* of the described Marginiferidae occurring outside of the Glass Mountains, as it possesses the prominent marginal band and general configuration. The two genera differ in the arrangement of the spines and in the development of the trails. *Marginifera* has numerous spines on the lateral slopes (Grant, 1968) whereas *Kozlowskia* has few and the Pakistan genus is not provided with a band of trails on the exterior.

DISCUSSION.—The various species of this genus have a distinctive form as well as a characteristic interior. Most of them are widely alate but when found are usually so broken at the hinge that their true width is seldom seen. Specimens dissolved from limestone best exhibit this important character, although some specimens preserving the points are occasionally found in matrix. Usually the specimens

are found weathered from shale and the ear points are seldom preserved in this type of occurrence.

Besides the ear points the bulbous nature of the pedicle valve and the peculiar geniculation posterior to the middle are equally distinctive. In some species the body of the shell is so bulbous that the length and width are almost equal. The sulcus is an evanescent feature commonly well formed in the Pennsylvanian species but less so in the Permian ones. *Kozlowskia splendens* (Norwood and Pratten) usually has on the pedicle valve a strong but narrow sulcus extending from the venter to the front margin, but the sulcus of *K. alata* and *K. subsphaeroidalis*, both new species, is very indifferently developed. Inasmuch as the presence of a fold is dependent on the formation of a sulcus, this feature of the brachial valve is evanescent.

The spine arrangement is generally fairly simple but is not the same in all species. Generally six strong spines, or modification of this arrangement occur on each species: a large spine on each ear, a large spine at the base of the lateral slopes, and two large spines on the trail. When favorably preserved, these spines are roughly arranged in a horizontal row around the body of the valve when it lies on its margins. All six spines are seldom preserved. In some species, at least in adulthood, no ear spine is developed. The large spine at the base of the lateral slopes is the end member of a row of four spines that curve from each side of the beak at the base of the lateral slope nearly to the front margin. The two trail spines may be two or several, but numerous trail spines are not usually present. Generally the umbonal region has few spines and the rest of the shell body has a few scattered spines.

The most diagnostic character of the genus is the concentration of trails in a narrow zone around the visceral area of the brachial valve. As the valves grow and the margin on the interior thickens and expands, a new trail is formed to close the anterior gap between the two valves. The older the specimens, usually the more trails; one specimen of *K. splendens* (Norwood and Pratten) (USNM 124027b) has 7 trails on the margin. Usually the brachial valve trail anterior to the margin is thin, delicate, and seldom preserved. Consequently, it is rare to find a specimen of *Kozlowskia* preserving any of its anterior trails. Specimens from USNM 705a are almost unique in preserving the last trail of the brachial valve almost entire. These speci-

mens too have an exceptional development of the marginal ridge.

The interior of the pedicle valve of most species is characterized by an elongated and elevated adductor platform. This is usually elongate and triangular in outline, with the anterior somewhat expanded. Two teardrop-shaped dendritic muscle scars can usually be distinguished. The diductor scars are flabellate and in *K. splendens* are located in front of the adductor platform. In this species the old portion of the diductor scar is covered by callus.

The ear baffles of the pedicle valve are usually well formed and close off a fairly spacious ear. The inner surface of the baffle and the inner side of the valve for some distance are generally strongly corrugated. In many specimens the ear baffles die out anteriorly, but in others they extend nearly to the front margin where they turn inward and unite medially, thus forming a low ridge around the visceral region.

The interior of the brachial valve is variable among species but most of them have some details preserved. The cardinal process is generally small but variable. It is the characteristic marginiferid type with a median depression and the median lobe inclined strongly posteriorly. The most exaggerated form of the cardinal process appears in *K. haydenensis* (Girty) in which the narrow median lobe is greatly curved posteriorly but anterior to it a great thickening of the base of the cardinal process is extended anterolaterally.

Lateral ridges are variably developed within species and within specimens of the same species. Commonly the groove behind the lateral ridge is deeply pitted to receive granules in a similar position on the pedicle valve. Ear baffles are strongly developed in all the species, and these are deeply corrugated on their outer face and interlock with the corrugations of the pedicle valve ear baffles. The marginal ridge extends anteriorly and medially from the ear baffle. In most specimens this is not extravagantly developed, but in *K. alata*, new species, it forms a shelf hanging over the inner surface of the trail. In one specimen of *K. haydenensis* the marginal ridge has grown inward so far that it has engulfed the distal ends of the long endospines.

The adductor platform and brevisseptum present no features different from other members of the

family. Generally they are moderately to strongly developed, but in some species bizarre thickenings are produced, as may be seen in *K. haydenensis* and *K. alata*. The same is true of the brachial ridges, which are enormously thickened in the former species.

STRATIGRAPHIC OCCURRENCE.—In the Glass Mountains *Kozlowskia* occurs in the Gaptank Formation, notably in bed 10 of P. B. King (1931). It is found in the Neal Ranch Formation but is rare; it is also rare in the Lenox Hills Formation. It is fairly common in the lower *Scacchinella* bed (Decie Ranch Member) of the Skinner Ranch Formation, which is its final appearance in the Glass Mountains.

*Kozlowskia alata*, new species

PLATE 312: FIGURES 1-20; PLATE 453: FIGURE 34

About medium size for genus, length and width variable, body usually subquadrate in outline; hinge forming widest part, commonly alate with acute, extended ears. Sides oblique and sloping medially; anterior margin gently rounded to nasute. Surface sculpture variable from nearly smooth to moderately strongly costate; costae variable, numerous and closely crowded. Spines long and slender, thin clusters just anterior to ears; several on posterior margin and one on ear extremity; rare or nonexistent on umbonal region and venter; few distantly scattered on trail slope. Brachial valve exterior obscurely costate and with posterior margin longitudinally wrinkled.

Pedicle valve strongly convex in lateral profile,

greatest curvature at narrowly humped venter; posterior region short and flattened, trail unusually long and fairly strongly convex. Anterior profile highly and narrowly domed, top of dome strongly rounded. Umbonal and visceral disc regions flattened and protruding only short distance posterior to posterior margin; trail somewhat abruptly bending away from venter, long, convex, and steep anteriorly. Sulcus evanescent, when present, usually appearing on venter, extending to anterior margin in some specimens but disappearing on trail in others. Trail in old or obese specimens developing narrowly rounded fold forming nasute anterior margin. Lateral slopes precipitate. Ears narrowly rounded, greatly extended.

Brachial valve with visceral disc region moderately concave, deepest near midvalve; trail sharply geniculated from visceral region, long and thin, usually with several layers; trail zone including three or four layers, forming fairly wide band on edge of geniculated part. Ears concave, widely extended, acute. Trail nasute in old specimens.

Pedicle valve interior with sharply and narrowly elevated adductor platform. Ear baffles large, strongly corrugated toward inside of valve, usually extended anteriorly around inside margin as low ridge.

Brachial valve with strong and thickened marginal band hanging over long, steep trail; cardinal process flattened, trilobed; lateral ridges strong, uniting with strongly corrugated ear baffles. Adductor platform consisting of two elongate, tear-shaped, elevated scars; brevisseptum strongly elevated distally; brachial ridges strongly thickened.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	mid- width	height	thick- ness
USNM 705a							
149800a	19.5	12.2	35.0	23.3	20.7	12.0	6.8
149800b	17.4	11.0	33.0	23.5	18.4	10.5	6.2
149800c	18.2	13.6	33.0	20.8	18.0	10.7	5.3
149800d	18.8	11.0	37.0	24.0*	17.8	12.0	6.8
(holotype)							
149800e	13.8	?	28.0	21.6*	16.9	9.4	?
149800f	13.7	10.9	24.0	23.4*	16.3	8.7	4.2
149800g	18.0	?	32.0	28.0	20.0	10.2	?
149800h	12.6	?	25.5	21.0*	15.1	8.7	?
149800i	14.6	11.0	27.5	18.0*	15.5	9.0	5.5
149800j	13.7	?	27.0	19.7	15.5	9.0	?
149800k	12.9	10.3	15.0	14.2?	14.1	8.7	?



STRATIGRAPHIC OCCURRENCE.—Cibolo Formation, Skinner Ranch Formation (*Scacchinella* beds at base = Decie Ranch Member).

LOCALITIES.—Cibolo: USNM 728-1. Decie Ranch: 705a, 720e, 720g, 733r.

DIAGNOSIS.—Large, widely alate *Kozlowskia* having a rounded quadrate shell body.

TYPES.—Holotype: USNM 149800d. figured paratypes: USNM 149799a, b; 149800b. Measured paratypes: USNM 149800a-c, e-k. Unfigured paratypes: USNM 149800a, c, e-k.

COMPARISONS.—This is a large species most like *K. kingi* Stehli from the lower Bone Spring Formation in the Sierra Diablo. The pedicle valve of the Glass Mountains species has a bulbous body like that of *K. kingi* but it is rounder, the length and width of the body being nearly equal. A sulcus is not well formed in *K. kingi* and is usually present only on a part of the trail in *K. alata* (if present). The front margin of *K. alata*, in old specimens tends to form a narrow fold, a feature not seen in any specimens of *K. kingi*. The umbonal and visceral regions of *K. alata* are more inflated than those of *K. kingi*. The brachial interiors of the two species are totally unlike in the development of their structures, those of *K. alata* being highly exaggerated.

DISCUSSION.—The tendency toward development of a nasute anterior appears to be a character thus far seen only in the Wolfcampian species. This tendency is very marked in old specimens of *K. alata*.

An exceptional feature of this species is the preservation of the trail anterior to the thickened margin, a structure that is usually broken away in this genus. In one specimen the marginal ridge forms a band about 1.5 mm wide around the anterior margin of the visceral disc and hangs over the trail, which is preserved for 7.5 mm, about half the valve length. Most of the other structures of the brachial valve in this species are strongly exaggerated but not thickened to the degree seen in some specimens of *K. haydenensis* (Girty).

### *Kozlowskia anterosulcata*, new species

PLATE 313: FIGURES 1-12

Small for genus, wider than long at hinge, ears widely extended and acute; sides sloping medially

and anterior margin broadly rounded and gently emarginate. Surface sculpture variable, visceral region with few fairly strong concentric wrinkles somewhat cancellated by radial costae. Costae fairly strong, broadly rounded, interspaces variable, usually narrower than costae, about 6 costae per 5 mm, at front margin of well-preserved specimens. Spines few, arrangement uncertain because of poor preservation.

Pedicle valve unevenly and narrowly convex in lateral profile, posterior half flattened, anterior half of trail surface gently convex, venter strongly bent; anterior commissure forming high dome with rounded and usually slightly indented top. Visceral disc and umbonal regions moderately swollen but flattened and with long gentle slopes. Geniculation strong, taking place at venter, forming angle between 45° and 65°. Sulcus originating on edge of visceral disc or venter, variable in strength, usually broad and moderately deep and extending to anterior margin; flanks bounding sulcus rounded and steep-sided. Ears narrowly rounded in section.

Brachial valve moderately concave and strongly geniculated; trail moderately long, fairly strongly costate. Ears well demarcated and flattened.

Pedicle valve interior not known. Brachial valve interior with strong corrugated ear baffle and wide marginal band.

MEASUREMENTS (in mm).—Brachial valve length and thickness unmeasurable.

	length	surface length	hinge width	midwidth	height
USNM 715					
149795a	10.0	17.0	20.0*	12.9	5.4
149795b	11.3	21.0	20.0*	13.4	6.4?
149795c	10.7	19.0	19.4	12.7?	5.3
149795d	11.8	22.0	20.2	15.3	6.4
149795e	11.1	24.0	14.4	13.3	7.0?
USNM 707j					
149793a	11.8	21.0	18.4	13.8	6.4
(holotype)					

STRATIGRAPHIC OCCURRENCE.—Lenox Hills Formation.

LOCALITIES.—USNM 707j, 712z, 715.

DIAGNOSIS.—Small alate *Kozlowskia* with flattened visceral area and sulcate trail.

TYPES.—Holotype: USNM 149793a. Figured paratypes: USNM 149795a, b. Measured paratypes: USNM 149795a-e.

COMPARISON.—This is a small and strongly alate species most resembling *K. nasuta*, new species. It is

unlike that species in having a flattened visceral disc region, a somewhat angular geniculated zone, and the trail sulcate from visceral disc to anterior margin. Its ornament, flattened visceral disc, and smaller size help to distinguish it from the South American *K. capaci* (d'Orbigny).

This is a rare species that has been found only in conglomeratic limestone with characteristic Wolfcampian cephalopods.

### *Kozlowskia finlayensis*, new species

PLATE 447: FIGURES 49–55

*Marginifera sublaevis* R. E. King (part), 1931:89, pl. 23: figs. 13a–c [not figs. 15, 19 (= *Anemonaria inflata* Cooper and Grant, 1969)].

Fairly large for genus, transversely rectangular in outline, length equal to two-thirds width; cardinal extremities with large(?) ears; lateral margins rounded but sloping medially; anterior margin broadly rounded, medially indented; surface covered by narrow costellae separated by spaces considerably wider than costellae; these best developed on the visceral disc region, becoming obsolete anteriorly on trail; visceral disc region marked by strong concentric rugae crossing costellae to produce subdued semireticulate pattern. Spines distant and scattered; broad row of 5 large spines on trail; smaller spines scattered over visceral region, on posterior margin, and on umbonal slopes.

Pedicle valve unevenly and angularly convex in lateral profile, visceral disc region flattened, trail gently convex, angle of geniculation about 85°; anterior profile broadly domed. Umbo flattened, scarcely protruding above hinge; visceral region slightly swollen; cardinal extremities slightly deflected in ventral direction; trail longer than visceral area, slightly convex and marked medially by sulcus originating at place of geniculation; sulcus narrow, moderately deep; anterior slope long and steep.

Brachial valve moderately deeply concave, most concave in median region; sides sloping steeply medially; cardinal extremities flattened. Position of subperipheral marginal ridge visible as darkened band; trail anterior to subperipheral band moderately long.

MEASUREMENTS (in mm).—From King locality 512, YPM 11802 (lectotype) length 14.8, surface length 24.0, brachial valve length 12.4, hinge width 21.0\*, midwidth 20.7, height 9.7, thickness 4.0?.

STRATIGRAPHIC OCCURRENCE.—“Leonard” Formation (just below ammonoid bed).

LOCALITY.—King locality 512: Fossil Hill, northwest Finlay Dome, north of Finlay, Texas.

TYPES.—Holotype: YPM 11802.

DIAGNOSIS.—*Kozlowskia* with angular lateral profile, well-ornamented visceral disc and strongly sulcate trail.

COMPARISON.—The lectotype is the only specimen of this species available for comparison with other species. It is most similar to *K. kingi* Stehli from the Sierra Diablo; indeed, King's cotype YPM 11796 belongs to this species. Several important differences between the two species appear, however, even at casual study. The lateral profile of Stehli's species is less angular than that of the Finlay Dome specimen, the former having a more inflated and more convex visceral region, although the two are similarly ornamented. The geniculation of *K. kingi* takes place more anteriorly, and the trail is never so strongly sulcate.

DISCUSSION.—The type lot of *Marginifera sublaevis* King consists of seven specimens two of them belonging to the University of Texas and the others to Peabody Museum, Yale University.

Two of the seven specimens are designated as cotypes and from these only the type must be selected. Specimen 11792a is selected and becomes *Anemonaria sublaevis* (R. E. King). Specimen T10051 is probably the same species. This leaves those still belonging to *Kozlowskia* without a name. Specimen YPM 11796 belongs to *K. kingi* Stehli, and specimen T9954 is unidentifiable. Specimen 11802 remains, without a name; for it we propose *K. finlayensis*.

### *Kozlowskia kingi* Stehli

PLATE 313: FIGURES 24–58; PLATE 314: FIGURES 21–45

*Kozlowskia kingi* Stehli, 1954:322, pl. 22: figs. 6–11.

*Marginifera sublaevis* R. E. King (part), 1931:89, pl. 23: figs. 14a–c.

Large for genus, strongly transverse with narrowly attenuated ears forming about 50° angle. Sides sloping medially; anterior margin broadly rounded to somewhat truncated, occasionally narrowly nasute. Anterior commissure with slight median emargination. Beak small and incurved slightly over opposite valve. Surface faintly costellate, costellae best exhibited on venter. Spines few and scattered,

usually in row along posterior margin, few on flanks, scattered on trail. Ears usually smooth but occasionally with one or more spines.

Pedicle valve unevenly convex in lateral profile; posterior or visceral region flattened to slightly convex; geniculated part narrowly rounded, forming angle of  $45^{\circ}$  to  $50^{\circ}$ ; anterior part, or trail, gently convex; anterior profile squarely domed, with steep sides, ears protruding widely. Umbonal region flatly convex; region anterior to geniculation inflated. Trail long, occupying about two-thirds of surface length. Sulcus usually present, narrow, shallow, originating at anterior end of venter, where geniculation takes place 10 mm anterior to beak. Flanks rounded and steep.

Brachial valve with posterior half of visceral region moderately concave, this portion surrounded

by steeply sloping trail. Ears prominent and narrowly rounded. Trail, when preserved, fairly long, not quite equal in length to length of visceral region.

Pedicle valve interior with strongly fluted, well-elevated ear baffles extending laterally to midvalve, continuous around outside of visceral area as low ridge. Adductor track elevated, narrow.

Brachial valve interior with small, sessile, typically marginiferid, cardinal process, low lateral ridges; ear baffles strong, fluted on outside, fluting extending anteriorly to where baffle turns medially to form anterior marginal ridge; endospines long and prominent, reaching 3 mm at midvalve. Adductor scars consisting of two large inside scars and two smaller outside scars. Brachial ridges strongly developed. Trail covered by small, nearly prostrate spines.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	mid- width	height	thick- ness
USNM 728f							
149805a	18.3	?	30.0	28.3	21.4	11.7	?
149805b	15.7	?	28.0	28.5	22.0	10.8	?
149805c	15.3	?	25.0	20.2	20.2	8.7	?
149805d	16.5	?	29.0	31.5	25.0	10.6	?
149805e	16.2	?	c.27.5	27.6	23.5	9.5	?
USNM 728e							
149803a	19.2	11.0	34.0	24.0	17.0	11.1	6.1
149803b	17.1	?	32.0	28.7	20.5	11.4	?
149803c	13.7	?	26.0	23.2	16.9	8.9	?
149803d	16.6	?	31.0	25.0	19.0	10.0	?
149803e	12.6	10.5	22.0	20.0	17.9	7.8	3.8

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation (lower), Skinner Ranch Formation (lower).

LOCALITIES.—Bone Spring: AMNH 497, 625, 628, 629, 631; USNM 725c, 728e, 728f, 728h, 742, 745, 746. Skinner Ranch: 716p.

DIAGNOSIS.—Large, alate *Kozlowskia* with subdued costellae and shallow sulcus.

TYPES.—Figured hypotypes: USNM 149803a, d, f-o, q; 149805a, c. Measured hypotypes: USNM 149803a-e, 149805a-e.

COMPARISON.—This species is the largest and most alate *Kozlowskia* so far described. It is most like *K. alata*, new species, but differs in its much wider outline, wider ears, and less bulbous form and umbonal region. Occasional specimens that have developed a nasute anterior suggest *K. alata* but they are unusual variants of *K. kingi*.

DISCUSSION.—This is one of the most abundant species in the lower Bone Spring of the Victorio Canyon region. It is also very well preserved in nearly all of its details. It is variable in the usual forms that productids take. Some specimens are narrower hinged, and there is variation in the degree to which the sulcus is developed. A few specimens, especially at USNM 728e, develop a narrow, nasute fold at the anterior although this feature is rare. Considerable variability is noticed in the development of the spines. Some specimens have few spines, whereas others may develop a fair number of small spines, especially in the visceral disc region.

The young are nearly flat and one of them has the characteristic attachment ring at the beak showing that this species, like many others, was fixed in its youthful stages.

*Kozłowskia nasuta*, new species

PLATE 313: FIGURES 13-23

Medium size for genus; subquadrate outline, hinge widely extended, ears long, acutely pointed having angle about  $60^\circ$ . Sides nearly straight and sloping strongly medially; anterior margin fairly strongly rounded and medially, narrowly nasute. Surface costellate, costellae crowded, interspaces narrower than costellae, strongest on venter and trail, subdued on visceral disc, absent from umbo. Concentric wrinkles few on visceral disc. Spines few; one large spine near ear extremity; row of three spines at base of lateral slopes, with anterior-most one large and thick; body spines few and widely scattered; spines on trail few.

Pedicle valve with uneven lateral profile, venter narrowly curved, visceral disc and umbonal regions short and flattened, trail moderately curved and long, much longer than visceral disc and umbo. Anterior profile moderately high, domed, with long, steeply sloping sides. Visceral disc and umbonal regions moderately inflated, presenting flattened profile; not protruding strongly posterior to hinge. Median region strongly inflated, geniculation taking place about one-third distance from beak. Sulcus narrow, shallow, originating at beak but disappearing near front margin, at locus of narrow median fold, or siphon. Flanks inflated and steep sided.

Brachial valve with costellae nearly obsolete on visceral disc region but stronger on trail; deepest near midvalve; ears moderately troughlike, demarcated by low flexure toward pedicle side. Anterior with five trails forming moderately wide band.

Pedicle valve interior with small and moderately thickened adductor platform; area on each side of beak and just anterior to posterior margin strongly granulose; ear baffles strong, obliquely corrugated on inside.

Brachial valve interior with small cardinal process; lateral ridges moderately developed, strongly granulose on posterior side. Ear baffles strong, extending into thick, long marginal ridge. Adductor platform widely divided, scars elongate, tear-shaped. Brachial ridges moderately developed. Endospines few, greatly elongated, measuring about 2 mm.

MEASUREMENTS (in mm).—Holotype USNM 149798: length 12.3 (Does not include length of si-

phon, 1 mm), surface length 23.5, hinge width 19.1, width 15.5, height 7.6.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (Beds 9-14).

LOCALITY.—USNM 701a.

DIAGNOSIS.—Small, alate *Kozłowskia* with nasute anterior margin.

TYPES.—Holotype: USNM 149798. Unfigured paratype: USNM 149798a.

COMPARISON.—This is a distinctive species by virtue of its unusual nasute anterior and the peculiar development of the endospines. It is most like *K. anterosulcata*, new species, but differs in having a bulbous median region rather than an angular geniculation, a discontinuous sulcus on the trail terminating in a narrow fold, and fairly strong costellae. Inside the brachial valve it is unique for the great length of the endospines. It is smaller, more slender, and thinner-shelled than *K. capaci* (d'Orbigny), which has broader costae, a much more pronounced fold, and no development of the nasute anterior.

DISCUSSION.—Three specimens only are known of this species but its characters seem so positive and well defined that it is recognized as distinct.

*Kozłowskia subsphaeroidalis*, new species

PLATE 314: FIGURES 1-20

Small to medium size, usually wider than long, hinge forming widest part; ears prominent and greatly extended; sides sloping medially; anterior margin flattened to broadly rounded. Outline generally subquadrate, usually slightly transverse. Surface sculpture variable, closely costellate, costae irregular in size, commonly obscure to obsolescent. Visceral disc region with distant concentric wrinkles; ears with few wrinkles. Spines slender; those on sides and posterior generally stronger, arranged in row along posterior margin; tip of ear naked or with one spine; base of lateral slope with row of four halteroid spines; umbonal region and venter with scattered short, curved, erect spines. Trail with row of spines not far posterior to anterior margin.

Pedicle valve unevenly convex in lateral profile, maximum curvature at venter, umbonal region strongly flattened, trail slope gently convex and long. Anterior profile forming steep-sided dome. Umbonal region flattened, with long gentle slopes

to lateral extremities. Angle of geniculation strong. Sulcus evanescent, usually not well developed but strong and extending from venter to margin in few specimens, but most lacking this feature. Ears long and narrowly rounded in section, acutely pointed and forming angle about 60°.

Brachial valve moderately convex with well-demarcated ears; trails strong, final trail occasionally preserved. Trails numbering three or four.

Pedicle valve interior with moderately thickened adductor field; ear baffles strong, with strong corrugations and continued anteriorly around inside of margin as low ridge.

Brachial valve interior with small cardinal process, moderately developed lateral ridges, and moderately thickened adductor field. Ear baffles strongly corrugated and uniting with moderately developed marginal ridge. Brachial ridges indistinct.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	mid- width	height	thick- ness
USNM 711p							
149797a	13.3	10.8	27.0	21.3	16.8	10.4?	5.9
(holotype)							
149797b	12.6	10.7	25.5	18.4	16.2	8.3	5.4
149797c	13.2	10.1	26.0	17.2	15.7	8.5	5.0
149797d	11.9	9.2	21.0	17.4	14.2	7.2	5.0
149797e	12.6	9.2	23.0	16.4*	12.6	7.8	4.9
149797f	12.5	10.1	26.0	21.4*	16.0	8.0	4.6
149797g	12.5	10.1	23.0	20.0	15.0	8.0?	4.6
149797h	12.3	10.0	23.0	18.3	15.7	8.4	4.0
149797i	11.4	9.0	23.0	15.8?	13.0	7.4	4.0
149797j	11.5	8.8	22.5	15.8?	13.2	7.7	5.0
149797k	10.2	8.3	21.0?	16.1	13.0	7.4	4.0
149797l	12.0?	9.8	20.0?	19.3	13.1?	6.8?	4.2
149797m	10.5	?	21.0	17.7	12.7	7.0	?
149797n	10.8	8.6	20.5	15.7	13.5	7.1	3.9
149797o	10.9	8.7	20.0	14.6?	12.8	7.0	3.6

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (*Scacchinella* bed in lower part).

LOCALITIES.—USNM 705a, 711p, 716p, 724p, 719y, 724q.

DIAGNOSIS.—Alate, transverse, nonsulcate *Kozlowskia* with bulbous body.

TYPES.—Holotype: USNM 149797a. Figured paratypes: USNM 149797b, k, p, q. Measured paratypes: USNM 149797b-o. Unfigured paratypes: USNM 149797c-j, l-o.

COMPARISONS.—This species is unlike *K. alata* and *K. nasuta*, both new species, in not having a tendency toward a nasute anterior margin even in old specimens. It differs from *K. alata* in size and in having a more transverse body. Its bulbous form separates it from *K. anterosulcata*, new species. It is readily distinguished from *K. kingi* Stehli in its smaller size, lack of a sulcus, and different ornament. It might be confused with *K. capacii* (d'Or-

bigny) but is less transverse, more finely costellate, and has a rounder lateral profile.

#### *Kozlowskia* species unidentified

Several specimens of *Kozlowskia* are too poorly preserved to merit description.

SPECIES.—Specimen USNM 149814, from the Neal Ranch Formation at USNM 701, is a large brachial valve about 25 mm wide and 15 mm from the cardinal process to the anterior edge of the marginal ridge. The anterior trail is missing except at the ears. The cardinal process is low and wide, the adductor platform fairly thick and the marginal ridge is strong. This valve suggests an exceptionally large species for this genus with its nearest relations to the larger varieties of *K. splendens* (Norwood and Pratten).



## Genus *Hystriculina* Muir-Wood and Cooper, 1960

*Hystriculina* Muir-Wood and Cooper, 1960:210.—Williams et al., 1965:H477.

Small, transversely rectangular or subquadrate outline, hinge usually forming widest part in adults. Anterior commissure usually sulcate, sulcus usually narrow but variable in development and becoming obsolescent anteriorly in some species. Brachial valve deeply concave; visceral cavity usually thin. Surface costate except for smooth umbonal region, costae usually obsolescent, crowded and with narrow interspaces. Surface sparsely spinose, spines all of halteroid type, rare along posterior margin, variable on ears and variously scattered on shell body; lateral spines usually long and stout; body spines generally shorter, curved and erect. Brachial valve without spines.

Pedicle valve interior generally with somewhat thickened adductor field and flabellate diductor scars. Ears usually concave and with variously developed baffles.

Brachial valve interior with variously developed lateral ridges, usually moderately strong, crossing ears as baffles and extended anteriorly to form submarginal ridge around sides and anterior, or dying out anterior to ears. Posterior platform usually not strongly developed and usually not strongly buttressing cardinal process; adductor field with smooth median scars on elevated, teardrop-shaped areas; outer scars small, nondendritic. Brevisseptum thin, elevated anteriorly, reaching about to midvalve; brachial ridges variously developed. Anterior slope usually endospinose.

TYPES-SPECIES.—*Hystriculina texana* Muir-Wood and Cooper (1960:210, pl. 64: figs. 1–10).

DIAGNOSIS.—Small Marginiferinae with obsolescent costae, sparsely spinose and without a submarginal ridge or with only a moderately developed submarginal ridge.

COMPARISONS.—*Hystriculina* may be confused with such other members of the Marginiferinae as *Marginifera* Waagen, *Desmoinesia* Hoare, *Kozlowskia* Fredericks, and *Elliottella* Stehli. It differs from *Marginifera* in the nature of the external ornament, in not having the lateral spines arranged as in that genus, and in lacking the strong development of the margin as in the Asiatic genus. *Desmoinesia* resembles *Hystriculina* on the ventral side but has a spinose brachial valve. *Kozlowskia* is

generally somewhat larger than most species of *Hystriculina* and generally is distinctly geniculated and more sparsely spinose than *Hystriculina*; it also possesses the distinctive trait of piling up trails anteriorly to form a thickened zone at the edge of the visceral disc, a feature never seen in *Hystriculina*.

*Elliottella* may easily be confused with *Hystriculina* but is generally more strongly costate, with the costae strong and deeply incised, a strong contrast to the irregular and obsolescent development of the costae in *Hystriculina*. Another external difference between the two genera is the fairly prominent concentric wrinkling seen on the visceral regions of both valves of *Elliottella*.

DISCUSSION.—Although *Hystriculina* is generally common in shaly facies, it is somewhat restricted in its occurrence in the Glass Mountains. Consequently, the material for study is not as abundant as that of many other genera, and some features of this genus are not as clear as might be hoped. This fact and the general variability of the species make understanding difficult.

One of the most important features is the subdued character of the radial ornament. Generally the umbonal region is smooth or nearly so but the remainder of both valves is covered by radial costae, variable in number and strength in each species, but constituting a good specific character except in extreme cases. Varices, or resting stages in growth, are more commonly conspicuous but variable wrinkles do not generally appear on either valve.

The spines and their arrangement are usually variable within a species and also between species but they conform to the usually marginiferinoid pattern of few spines. *Hystriculina* usually has few spines on the posterior margin. The ears, up to mature adulthood, may lack spines; however, in some species the ears in young adults may bear a large terminal spine arising from the angle. In other species this spine may not form until late adulthood. Generally a row of spines may be detected along the base of the lateral slope as in many other marginiferoid genera. The body spines are extremely variable in number among and within species. Generally the genus can be described as sparsely spinose.

The sulcus and, consequently, the fold are also variable. The genus may be said to be a sulcate form because a sulcus is invariably present on some part

of the median region of the shell. Usually the sulcus originates on or near the umbonal region and extends to the anterior margin. Generally it is moderately deep and usually narrow and U-shaped. In *H. ventroplana*, new species, most specimens have the fold well developed near its origin at the umbonal region and across the venter, but it gradually disappears in a general flattening of the trail a short distance posterior to the margin. A few specimens of *H. sulcata*, new species, which is normally strongly sulcate, also appear to lose the sulcus near the front margin.

Inasmuch as the development of the fold depends on that of the sulcus, this is even more variable than the sulcus. Most specimens are provided with a low fold that originates near midvalve but its strength varies from barely visible to a strong subcarinate ridge.

The pedicle interior furnishes few positive generic characters. The adductor field is generally somewhat thickened but the diductor scars are seldom seen. The ear baffles are another variable feature; they are strong in some species but non-existent in others.

The brachial interior does not offer distinctive generic characters, thus making generic determination uncertain in the absence of the opposite valve or of the exterior. The marginal ridges are extremely variable, usually moderately to strongly developed, and, in such cases, commonly extended across the ears as striated baffles. In some, these extend anteriorly nearly to the front margin and then die out. More rarely these ridges extend to the front margin and then medially unite at midvalve to form a marginal ridge. A well-defined marginal ridge is rare and it never reaches the strength of that of *Marginifera*.

Few immature specimens of *Hystriculina* were recovered from the residues; consequently, little is known about the growth and development of the shell. The umbonal regions of the few young studied indicate development in the manner common among the Marginiferinae, i. e., by the formation of an umbonal attachment ring and subsequent freedom on the sea bottom (Grant, 1968).

*Hystriculina* is common in the Pennsylvanian sediments of midcontinental United States. It is also fairly common in shaly parts of the Permian in the same region. In the Glass Mountains it is generally rare, and is found mostly in Wolfcampian

sediments. Inasmuch as most of the etched material is derived from biohermal limestones, an environment rare in the Pennsylvanian and Permian outside of West Texas, the genus is rare in the collection. Most of the shale areas in the Glass Mountains are restricted and have been so frequently collected by so many paleontologists that they are now virtually exhausted. *Hystriculina* is commonest in the Neal Ranch Formation, where it is represented by the new species *H. convexa*, *H. minima*, and *H. sulcata*. The last-named species also occurs in the *Uddenites*-bearing Shale Member, which contains the species *H. ventroplana*, new species. In the goniatite bed of the Lenox Hills Formation *H. dugoutensis* (R. E. King) is a rare species. As with many other Wolfcampian types, *Hystriculina* ranges into the Skinner Ranch Formation (basal *Scacchinella* bed), where it is represented by *H. pumila*, new species.

### *Hystriculina convexa*, new species

PLATE 325: FIGURES 1-24

About medium for genus, wider than long; transversely subrectangular in outline, hinge forming widest part; ears prominent, acute. Sides rounded and sloping medially; anterior margin broadly rounded to somewhat truncated. Surface irregularly costate, costae crowded, with narrow interspaces. Spines moderately long, stout on flanks, shorter and curved on body; one on ear in adults, about three in row at base of lateral slopes, and fairly numerous spines scattered on body of shell.

Pedicle valve strongly convex in lateral profile, greatest convexity at venter, umbonal region somewhat flattened. Anterior profile strongly domed and with steep sides, top slightly indented. Umbonal region narrowly and flatly convex; median region inflated, trail long and moderately convex. Sulcus originating on anterior side of umbonal region, variable, deepest in median part of trail, becoming obsolete at anterior in many specimens but reaching margin of others. Flanks inflated.

Brachial valve most concave near midvalve, with moderately steep sides and anterior; umbonal region moderately deeply depressed; ears small and well demarcated by ridge; fold low, variable, usually poorly defined. Surface, costate and coarsely dimpled, corresponding to spines of pedicle valve.

Pedicle valve interior with strongly thickened

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	mid- width	height	thick- ness
USNM 701d							
149764a	11.3	9.0	22.0	14.6	13.8	7.6	4.0
(holotype)							
149765a	12.1	?	23.0	16.5	15.5	7.0	?
149765b	11.6	?	22.0	16.0	14.4	7.5?	?
149765c	10.5	8.3	20.5	12.8*	13.5	6.6	3.6
149765d	11.1	8.4	20.0	15.0	12.8	6.9	2.7
149765e	10.5	8.0	19.0	13.8	13.0	6.3	3.6
149765f	10.0	8.0	17.0	13.8*	12.3	5.5	2.2
149765g	8.4	7.0	13.0	8.0	10.5	4.5	1.8
149765h	8.1	7.2	12.0	6.6	9.7	3.3	1.5
149765i	6.1	5.1	9.0	5.4	7.0	2.1	1.9

adductor field; ear baffles strong, forming decided ridge across ears in most specimens.

Brachial valve interior with fairly strong lateral ridges joining strong baffles across ears, continuing anteriorly and medially as irregularly developed submarginal ridge. Cardinal process small. Adductor scars moderately thickened, elongate. Brevisep-tum low; brachial ridges usually present, variously developed.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch For-mation (beds 9–14), Lenox Hill Formation.

LOCALITIES.—Neal Ranch: USNM 701, 701d, 701k, 712w, 715e. Lenox Hills: USNM 713y.

DIAGNOSIS.—*Hystriculina* of medium size with variable sulcus tending toward obsolescence ante-riorly.

TYPES.—Holotype: USNM 149764a. Figured paratypes: USNM 149764b–d; 149765d, e. Measured paratypes: USNM 149765a–i. Unfigured paratypes: USNM 149765a–c, f, i.

COMPARISONS.—This species is most comparable to *H. sulcata*, new species, in size and ornament. It differs in having a lesser development of the sulcus, that of *H. convexa* tending toward obsolescence and thus giving a convex appearance to the specimens. It is not as robust a species as *H. sulcata*, new species, and the spines tend to be more delicate than those of the latter. Furthermore, in the adult form, the umbonal region of *H. convexa* is lower and less extended posterior to the posterior margin than in *H. sulcata*.

*Hystriculina convexa* shares the character of anterior obsolescence of the sulcus with *H. ventro-*

*plana*, a new species that does not attain the size of *H. convexa* and has the sulcus even less devel-oped.

*Hystriculina dugoutensis* (R. E. King)

PLATE 445: FIGURES 33–51

*Marginifera dugoutensis* R. E. King, 1931:87, pl. 21: figs. 6, 7.

Small, transversely rectangular in outline, hinge forming widest part; ears moderately extended and generally acute; sides nearly straight, sloping medi-ally. Anterior margin broadly rounded, deeply in-dented. Surface costate, costae gently rounded, in-terspaces narrower than costae. Spines few, large: one on ear, row of three at base of lateral slopes, and few scattered spines on shell body.

Pedicle valve with lateral profile strongly convex, most convex at venter; visceral and umbonal regions flattened. Anterior profile broadly domed, sides sloping steeply, median region deeply emargin-ated. Umbonal region narrow and rounded; sulcus

## MEASUREMENTS (in mm).—

	length	surface length	hinge width	midwidth	height
USNM 715					
YPM 11773a	10.0	16.0	16.4*	14.1	5.6?
(lectotype)					
149754a	9.6	15.0	14.8	13.7	5.4?
149754b	9.6	15.0	14.5	13.0	5.0?
149754c	10.4	?	?	?	3.0
YPM 11773b	9.8	15.0	?	10.9+	5.0?
(paratype)					

originating on umbonal region, narrow and deep, forming broad V; flanks swollen and narrowly rounded. Umbonal slopes to posterolateral extremities steep.

Brachial valve deeply concave, strong median fold originating near umbo.

King (1931) described two specimens which are unlike in many particulars although both of them are strongly sulcate. The specimen chosen as lectotype (YPM 11773a) is the wider of the two and is better formed. This has a deep V-shaped sulcus bounded by narrow flanks and is typical of the species as shown by the additional specimens collected by parties from the U.S. National Museum of Natural History. The paratype (YPM 11773b) has a more even lateral profile, with less flattening of the umbonal and visceral regions. In dorsal view the umbo of 11773b is strongly swollen and elevated far beyond the posterior margin. In 11773a, on the other hand, the umbo is low and very narrowly rounded and scarcely protrudes beyond the posterior margin. The sulcus of 11773b originates slightly farther anterior than in the other specimen, but is entirely different from that of the lectotype. In 11773a the sulcus is broad, deep, and somewhat V-shaped whereas in 11773b the sulcus makes a narrow gash from umbo to anterior margin, and is shallow and U-shaped. The flanks bounding the sulcus of 11773b appear more inflated and less narrowly rounded, and the cardinal extremities are not preserved. Surface markings and spine arrangement are similar in the two.

No other specimen like YPM 11773b was seen in the USNM material of this species. Inasmuch as the ornament, the sulcus, and the measurements indicate a specimen close to *H. dugoutensis*, this

paratype is regarded as an aberrant member of this species.

STRATIGRAPHIC OCCURRENCE.—Lenox Hills Formation (Goniatite bed).

LOCALITY.—USNM 715.

DIAGNOSIS.—Strongly and deeply sulcate *Hystri culina*, with strong fold on brachial valve.

TYPES.—Lectotype: YPM 11773a. Figured paratype: YPM 11773b. Figured hypotypes USNM: 149754a-c. Measured hypotypes: USNM 149754a-c.

COMPARISONS.—This is the most strongly sulcate *Hystri culina* known and is thus readily distinguishable from described forms.

DISCUSSION.—This rare species was only found at the locality cited. Few specimens were taken and these are usually indifferently preserved, so it is difficult to obtain a whole specimen. Consequently, we are unable to give complete measurements. The information on the brachial valve was obtained from a complete specimen, partly filled with crystalline calcite, which went to pieces during an attempt to excavate the brachial valve. Nevertheless, enough was obtained to understand that valve.

### *Hystri culina minima*, new species

PLATE 315: FIGURES 1-23

Small, transversely subrectangular outline, hinge equal to widest part of adults; sides gently rounded, sloping medially; anterior margin gently rounded to nearly straight. Ears fairly large, nearly right angle or acute in adults. Surface costate; costae low, broadly rounded with narrow interspaces, often subdued and obscure, about seven per 5 mm at front, curved row of four at base of lateral slopes; distantly scattered spines on umbonal region, venter,

#### MEASUREMENTS (in mm).—*Hystri culina minima*, new species:

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 701d							
153898a	10.6	8.2	16.0	12.8	12.0	6.8	3.0
(holotype)							
159773a	9.6	7.5	17.0	11.6	11.6	5.2	1.8
149773b	10.2	7.8	19.0?	11.0	11.5	6.1	3.6
149773c	8.9	7.2	16.5	16.5	10.9	5.2	2.2
149773d	10.2	7.8	20.0	14.0?	11.5	6.2	3.4
149773e	9.0	7.3	16.0	12.4?	10.7	5.4	2.0
149773f	11.0	8.8	20.5	13.0?	12.8	6.0	3.0

and trail. Ears and posterior margin lacking spines.

Pedicle valve fairly strongly convex in lateral profile, most convex in posterior half; anterior profile steep-sided dome with well-rounded crest. Umbonal region narrowly swollen and protruding moderately posterior to posterior margin; median region inflated; sulcus usually not developed, but if present, shallow and inconspicuous, not reaching anterior margin. Flanks rounded.

Brachial valve fairly and evenly concave, deepest at midvalve and surrounded by steep slopes. Umbonal region deeply depressed. Ears demarcated by oblique flexure, gently concave. Costae usually obscure.

Pedicle valve interior with adductor scars on moderately swollen platform. Ear baffles not developed.

Brachial valve interior with fairly large erect cardinal process (for small shell); adductor scars on moderately thick platform, elongate, teardrop-shaped. Lateral ridges not developed; ear baffles low and inconspicuous; endospines in narrow band on venter; trail slope costate and granulose.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (Beds 2–14 of P. B. King).

LOCALITIES.—USNM 701, 701a, 701a<sup>1</sup>, 701a<sup>3</sup>, 701c, 701d, 701h, 721g.

DIAGNOSIS.—Small and compact *Hystriculina* with poorly developed fold and sulcus.

TYPES.—Holotype: USNM 153898a. Figured paratypes: USNM 149773d, f; 153898b–d. Measured paratypes: USNM 149773a–f. Unfigured paratypes: USNM 149773a–c, e, g.

COMPARISONS.—This is a small species comparable to *H. pumila*, new species, from which it differs in

its less regular costation, lesser development of a sulcus, and more rounded outline. It is also smaller than *H. ventroplana*, new species, and does not have the sulcus confined to midvalve as in that species.

### *Hystriculina pumila*, new species

PLATE 315: FIGURES 24–47

Small, wider than long, transversely subrectangular outline; hinge widest part of adults; sides gently rounded; anterior margin nearly straight, slightly indented medially; anterolateral extremities narrowly rounded. Ears fairly large, forming acute angle in adults. Surface marked by closely crowded, broadly rounded costae, variable in size and strength of development (possibly a function of preservation). Costae of large adult numbering 8 or 9 on flanks and 4 in sulcus. Spines numerous, all of halteroid type; a sparse row on posterior margin and angle of ear, a curved row at base of lateral slope, and numerous spines scattered over umbonal region, venter, and trail. Body spines generally erect, curved anteriorly, usually short, attaining length of 5 or 6 mm; lateral spines longer and stouter, approaching 10 mm in length.

Pedicle valve moderately convex in lateral profile, maximum curvature in posterior third, umbonal region slightly flattened; anterior profile domed with steeply sloping sides and medially indented top. Umbonal region moderately inflated and moderately protuberant posterior to posterior margin. Posteromedian region strongly inflated; trail long and convex. Sulcus originating on venter,

#### MEASUREMENTS (in mm).—*Hystriculina pumila*, new species:

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 711p							
149759a	10.6	8.2	20.0	13.2	12.7	5.9	2.8
149759b	10.1	7.7	19.0	12.6	11.7	5.9	2.7
(holotype)							
149759c	9.7	7.6	18.0	11.4	11.2	5.7	2.3
149759d	9.2	7.5	16.0	12.2?	11.8	5.3	2.2
149759e	9.2	7.4	17.0	11.7	11.0	5.0	2.5
149759f	8.1	6.3	15.5	10.5	9.5	4.7	2.0
149759g	7.7	6.4	14.0	8.8	9.1	4.9	1.6
149759h	7.4	?	11.5	9.0	9.2	3.7	?
149759i	6.8	?	10.5	6.5	7.7	2.8	?
149759j	6.2	5.6	9.0	6.2	6.8	2.8	1.1



shallow and narrow, occupied by two to four costae; flanks bounding sulcus well rounded and with steep sides. Ears triangular, gently convex.

Brachial valve deeply and fairly evenly concave, deepest medially, with strongly sloping sides and front; ears well demarcated by oblique ridge; fold low and inconspicuous, originating near midvalve. Surface costate and indented by dimples corresponding to spines of pedicle valve.

Pedicle valve interior with small development of adductor platform and poorly formed ear baffles.

Brachial valve interior with fairly strong lateral ridges extending anterolaterally to form low baffles across ears and continuing anteriorly to form indistinct submarginal ridge. Cardinal process small, on moderately developed posterior platform. Median adductor pair consisting of tear-shaped marks moderately thickened and elevated. Brevisseptum low; brachial ridges moderately developed.

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (lower).

LOCALITIES.—USNM 707w, 711p, 712p, 715v, 719y, 724p, 724q.

DIAGNOSIS.—Small *Hystriculina* with strong costae and moderately developed sulcus.

TYPES.—Holotype: USNM 149759b. Figured paratypes: USNM 149759c, j-n. Measured paratypes: USNM 149759a, c-j. Unfigured paratypes: USNM 149759a, d-i.

COMPARISONS.—This species is compared with *H. minima*, new species, the species most like it, under that heading. The strong and fairly constant costae make the species unique in this genus. This is the youngest species of *Hystriculina* known in the Glass Mountains.

*Hystriculina sulcata*, new species

PLATE 233: FIGURES 1-39

?*Marginifera wabashensis* R. E. King (not Norwood and Pratten), 1931:91, pl. 23: fig. 4.

About maximum size for genus, wider than long, maximum width usually at hinge; transversely subrectangular in outline; sides gently rounded and sloping medially; anterior margin broadly rounded and narrowly indented medially. Ear small, narrowly rounded in section, bluntly pointed but usually forming slightly acute angle. Surface ornament variable, consisting of faint, subdued costae,

MEASUREMENTS (in mm).—*Hystriculina sulcata*, new species:

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 701							
149718a	12.3	9.4	22.0	16.7	14.7	8.4	?
149718b	11.9	9.5	21.0	15.7	15.4	7.8	2.8
(holotype)							
149718c	12.8	9.7	23.0	15.6	14.7	8.0	2.4
149718d	12.2	9.5	23.5	16.0	14.9	7.9	3.5
149718e	12.0	8.3	23.0	14.4	13.9	7.8	2.1
149718f	10.5	7.7	18.5	14.6	13.4	6.7	3.0
149718g	10.5	?	17.5	13.6?	13.6	5.4	?
149718h	9.0	7.4	15.0	12.8	11.7	5.0	1.8
149718i	8.3	6.8	12.5	11.7	11.7	4.1	0.6
149718j	8.1	6.5	12.0	8.4?	10.0	3.3	1.0
149718k	5.9	4.9?	8.0	7.0	7.9	2.4	1.2
149718l	12.5	9.6	23.0	16.0	15.7	8.6	3.1
149718m	11.9	8.7	23.0	15.9	14.6	8.1	3.5
149718n	12.8	9.3	23.0	15.5	14.7	7.5	3.1
149718o	13.2	?	26.0	18.2	16.2	6.8	?
USNM 701-1							
149724a	15.3	11.0	30.0	21.0	17.8	10.8	4.2
149724b	12.8	9.4	24.0	17.2	14.9	7.7	3.7
149724c	11.3	9.4	19.5	15.0	14.4	6.6	2.8
149724d	11.9	?	23.0	15.8	14.7	6.5	?

broadly rounded, and with narrow spaces between costae. Spines wholly halteroid, few in number; two on lateral slope over ear and others scattered distantly on umbonal region, venter, and trail. Ears and posterior margin spineless.

Pedicle valve strongly convex in lateral profile, venter most strongly curved, umbonal region somewhat flattened. Anterior profile strongly elevated, domed; deeply indented medially flanks well rounded, sides steep. Umbonal region flatly convex; median region inflated. Sulcus originating on anterior side of umbonal region, narrow and continuous to anterior margin. Umbonal region low, not extending conspicuously posterior to posterior margin.

Brachial valve deepest medially and divided longitudinally by low, rounded fold originating posterior to midvalve. Ears flatly concave and with margins elevated, demarcated from concave area by oblique ridge. Slopes to midvalve steep.

Pedicle valve interior with adductor callosity on posterior of median ridge, in old shells forming platform expanding in width anteriorly. Ear baffles not well developed.

Brachial valve interior with small, stout cardinal process on moderately developed posterior platform; lateral ridges low, oblique extending anterolaterally to meet ear baffles; submarginal ridge present only in old shells, extending from externally striated ear baffle anteriorly and medially. Brevisseptum short; brachial ridges moderately developed. Endospines short and stout, scattered on anterior slope.

**STRATIGRAPHIC OCCURRENCE.**—Gaptank Formation (*Uddenites*-bearing Shale Member), Neal Ranch Formation (beds 2, 4, 9–14 of P. B. King), Lenox Hills Formation, possibly also Hess Formation.

**LOCALITIES.**—Gaptank: USNM 715z. *Uddenites*: USNM 701e, 701f, 701p, 701q, 701r, 701t, 701v, 702q, 703p, 705h, 713a. Neal Ranch: USNM 701, 701c, 701d, 701k, 701–1, 727e. Lenox Hills: USNM 704f, 704r?, 707m, 709t, 716r. Hess?: USNM 719q.

**DIAGNOSIS.**—Strongly sulcate, subquadrate *Hystriulina*.

**TYPES.**—Holotype: USNM 149718b. Figured paratypes: USNM 149718-l, n-p; 154235b, e, f. Measured paratypes: USNM 149718a, c-o; 149724a-d. Unfigured paratypes: USNM 149718a-k, m; 154235a, c, d.

**COMPARISONS.**—This is a fairly large species and, therefore, should be compared to *H. ventroplana* and *H. convexa*, both new species, and *H. dugoutensis* (R. E. King). Distinction between this species and *H. ventroplana* is easy because the sulcus of the latter becomes obsolescent anteriorly in the adult and its costae are less strongly developed than in *H. sulcata*. Comparison with *H. convexa* is made under that species.

*Hystriulina texana* Muir-Wood and Cooper is strongly sulcate in most of its specimens although it is variable. It is a much wider and generally smaller species and has a lower umbonal region than that of *H. sulcata*. *Hystriulina dugoutensis* (R. E. King) is much more strongly sulcate and proportionately wider than *H. sulcata* and has narrowly rounded flanks. The two species are entirely unlike.

### *Hystriulina ventroplana*, new species

PLATE 315: FIGURES 48–72

Small, slightly wider than long, subquadrate outline; hinge usually slightly wider than midwidth; ears small, slightly acute. Sides gently rounded, sloping slightly medially. Anterior margin moderately and broadly rounded. Surface obscurely costate, costae subdued and irregular, worn specimens suggesting smooth shell. Spines few in number; three on lateral slopes over ears, rest scattered on shell body; one spine on ear extremities in adults.

Pedicle valve strongly convex in lateral profile, greatest curvature near venter, umbonal region flattened. Anterior profile high, steep-sided dome with gently rounded crest. Umbonal region broad but flatly convex, protruding conspicuously posterior to hinge. Median region inflated; trail long and gently convex. Sulcus inconspicuous, originating on venter but merging with trail surface anteriorly and, in adults, not visible near front margin. Flanks rounded and steep-sided.

Brachial valve deeply concave, maximum curvature near midvalve; anterior and sides steeply dipping toward midvalve. Ears flattened and well demarcated by low ridge. Fold low, poorly developed.

Pedicle valve interior with small adductor platform moderately thickened; ear baffles poorly developed, interior strongly striated anterior to ear.

Brachial valve interior with fairly large cardinal process, strong lateral ridges and ear baffles extended anteriorly nearly to front margin; adductor field moderately thickened.

MEASUREMENTS (in mm).—Brachial valve length unmeasurable, except USNM 149777b, 9.2.

	length	sur- face length	hinge width	mid- width	height	thick- ness
USNM 701v						
149785a	11.8	21.5	15.0	14.2	6.9?	?
149785b	12.0	21.0	13.0	12.7	6.8?	
USNM 701q						
149783a	11.7	20.0	13.9	12.2	6.7?	?
149783b	10.9	20.0	13.1	12.6	7.0?	?
149783c	11.5?	21.5?	14.6	13.3	5.8?	?
149783d	11.6	21.5	14.1	13.0	7.7?	?
149783e	11.3	20.5	13.7	12.7	6.7?	?
149783f	11.4	21.0	13.6*	12.5?	7.4?	3.1
USNM 701e						
149780a	10.7	20.5	12.8	12.3	6.2	?
USNM 701						
149777b	11.8	23.0	12.8	13.3	7.8	3.0
(holotype)						

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member) Neal Ranch Formation (beds 2, 9–14 of P. B. King).

LOCALITIES.—*Uddenites*: USNM 701e, 701p, 701q, 701v, 701y. Neal Ranch: USNM 701, 701a, 715b, 719r.

DIAGNOSIS.—Subquadrate *Hystriculina* with inconspicuous sulcus at midvalve but no sulcus on anterior part of trail.

TYPES.—Holotype: USNM 149777b. Figured paratypes: USNM 149777a-c; 149783a, b. Measured paratypes: USNM 149780a; 149783a-f; 149785a, b. Unfigured paratypes: USNM 149780, 149783c-f, 149785a.

COMPARISONS.—This species is readily distinguished from all described *Hystriculina* by the subdued ornament and the obsolescence of the sulcus anteriorly, although it may be fairly strong at midvalve.

### Subfamily COSTISPINIFERINAE Muir-Wood and Cooper, 1960

Marginiferidae with crenulated ridges extending across the ears of both valves; prominent endospines in row anterior to septum, and also a set on outer margin of brachial ridges; adductors smooth or rarely partly dendritic.

Genera in West Texas: *Costispinifera* Muir-Wood and Cooper, 1960; *Bothrionia*, new genus; *Elliottella* Stehli, 1954; *Echinauris* Muir-Wood and Cooper, 1960; *Oncosarina* Cooper and Grant, 1969.

Two of the five genera are abundantly represented in the Glass Mountains, *Elliottella* is abundant in the Sierra Diablo but *Bothrionia* and *Oncosarina* are rare. *Bothrionia* is known only from Guadalupian strata in the Guadalupe and Glass Mountains, in both of which it is rare. *Oncosarina* is fairly common and characteristic of the upper part of the Skinner Ranch Formation in the Glass Mountains. *Costispinifera*, characteristic of the Early Guadalupian, is common in the Glass Mountains but rare in the Guadalupe Mountains. *Elliottella*, which characterizes the Skinner Ranch in the Glass Mountains and its correlative in the Sierra Diablo is common in the latter but rare in the Glass Mountains.

*Liosotella* Cooper which had hitherto been placed in this family is now known to possess a zygidium and has been transferred to the Paucispiniferidae. *Nudauris* Stehli is here referred to the Dictyoclostidae.

### *Bothrionia*, new genus

[Greek *bothrion* (little pit)]

Small, transverse and wide-hinged Marginiferidae, deeply concavo-convex; anterior margin strongly nasute, giving shell subtriangular outline when well preserved. Surface costellate, costellae narrow, discontinuous in some specimens. Surface sparsely spinose; few spines on the posterior margin, large one near angular extremity of each ear, row at base of lateral slopes, scattered spines on visceral disc and trail, especially on anterior part of latter. Sulcus inverting to fold anteriorly.

Pedicle valve interior with ear baffles moderately to strongly developed, continued anteriorly to form ringlike ridge around visceral area. Muscle scars lightly impressed; no adductor platform.

Brachial valve interior with strong oblique lateral ridges extending anterolaterally from cardinal process; ear baffles inconspicuous or not developed. Cardinal process sessile, trilobed but without zygidium. Posterior platform strongly developed in old shells and extended anteriorly to separate adductor scars and partly enclose proximal part of brevis-septum. Adductor scars four in number, one pair

median but other two on outside of inner ones; scars small, median scars narrowly oval and not lobed. Brevisseptum slender blade, free distally. Brachial ridges strong and narrowly looped. Endospines numerous, long and slender.

TYPE-SPECIES.—*Bothrionia nasuta*, new species.

DIAGNOSIS.—Nasute Marginiferidae with sulcus reverting to a fold in the pedicle valve and a strong marginal rim around the visceral region of the pedicle valve.

COMPARISONS.—No described genus is quite like this one externally, but *Paramarginifera* Fredericks from the Permian of the Urals has an interior margin in the pedicle valve like that of *Bothrionia*. The exterior of *Paramarginifera*, however, with its fine costellae, long, nonsulcate trail, and different spine arrangement, is entirely unlike the Glass Mountains genus.

*Haydenella* Reed from the Permian of the Salt Range of Pakistan is also similar, having in common the narrow visceral cavity and a row of spines along the base of the lateral slopes. This genus is also costellate and nonsulcate; consequently, it cannot be confused with *Bothrionia*.

*Rugivestis* Muir-Wood and Cooper is a somewhat exaggerated form having essentially the characters of *Bothrionia* but its brachial valve interior is not wholly known. In *Rugivestis* the umbonal and visceral regions are reticulated, and the sulcus is short and reverts to a fold at the anterior. The "nose" at the anterior, instead of being like that of *Bothrionia*, is elevated, elongated, and carinate but does not protrude beyond the front margin, as in *Bothrionia*. The interior of *Rugivestis*, like that of *Bothrionia*, is provided with a thickened rim around the visceral disc of the pedicle valve. The brachial valve of the Oregon genus appears to have been delicate but other features are not known. The two genera are unlike in detail but are certainly related and should be assigned to the same family.

*Productus subpusillus* Licharew (1937:40, 107, pl. 3: figs. 7–13) from the "Upper" Permian (P<sub>2</sub>) of the North Caucasus belongs to this genus. Licharew's figure 7 shows a fine and typical brachial valve interior.

DISCUSSION.—*Bothrionia* is rare in the Glass and Guadalupe mountains. Although the material at hand is adequate for description and illustration, it does not provide a good growth series, and the number of brachial valves is small. The full range of

variation of inner and outer details is thus not available.

The unusual feature of the exterior is the sulcus, which originates on the venter, extends for about half the valve length, and then abruptly reverts to a narrow fold that is extended anteriorly beyond the anterior margin as a semitube. This nasute projection thus gives the exterior a definitely triangular outline.

The interior of the pedicle valve is unusual in the light impression of the muscle field and the lack of an adductor platform. The most pronounced feature of the pedicle valve interior is the strong rim around the inside of the visceral cavity. As in many other productids the bases of the exterior spines, especially of the lateral rows, is extended into the interior.

The brachial valve is distinctive for the great development of long and slender strainer spines. They occupy a broad band at the place of geniculation, and extend for some distance down the slope of the trail.

The cardinal process is small and typically marginiferid but has no supporting zygidium. It and the midvalve are greatly thickened by the formation of a posterior platform anterior to the cardinal process. This platform is extended laterally along the inside of the lateral plates and anteriorly between the adductor pairs to enclose the posterior end of the brevisseptum. The brachial ridges do not extend directly laterally but are given off obliquely toward the anterolateral extremities. In one specimen the inner end of the loop is thickened and elevated.

### *Bothrionia guadalupensis*, new species

PLATE 316: FIGURES 27–51

Subtriangular to narrowly semielliptical outline, sides sloping rapidly medially, anterior margin broadly rounded to nasute, depending on age. Ears large, subulate, acutely pointed. Surface marked by irregular subdued, closely crowded costae, 3 to 5 per 5 mm on slope of trail. Spines as usual for genus.

Pedicle valve moderately convex in lateral profile, umbonal region abruptly curved, venter and trail forming long, convex, and moderately steep slope; anterior profile narrowly domed, sides steeply slop-

ing. Sulcus poorly defined, narrow and shallow, originating just anterior to umbonal region but disappearing about one-quarter valve length posterior to anterior margin; flanks swollen and steep-sided. Anteromedian extremity drawn into narrow tubelike fold, not preserved in young specimens.

Brachial valve deeply concave with steeply sloping sides and anterior; ears concave and well demarcated. Fold scarcely defined.

Pedicle valve interior with thickened rim around visceral cavity deeply inset with long rim on sides and front. Muscles lightly impressed. Brachial valve interior with high, thin brevisseptum and very long endospines on trail slope.

MEASUREMENTS (in mm).—From locality USNM 728, specimens 149628a and d (holotype), respectively: length 17.6, 14.1; brachial valve length (?), 11.5; surface length 30.3, 21.0; hinge width 21.6, 17.8; midwidth 19.6, 17.4; height 9.5, 7.4; thickness (?), 3.4.

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member).

LOCALITIES.—AMNH 512, USNM 728.

DIAGNOSIS.—Large, transverse *Bothrionia* with large ears, subdued costae, and a large visceral cavity.

TYPES.—Holotype: USNM 149628d. Figured paratypes: USNM 149628a-c, e, f. Measured paratypes: USNM 149628a.

COMPARISONS.—Because of its size and transverse form, this species is directly comparable to

*B. transversa*, new species, from the Glass Mountains but is totally unlike *B. pulchra*, new species, the only other species from the Guadalupe Mountains. It differs from *B. transversa* in the less prominent ribbing, the slighter development of the sulcus, and the less inflated umbonal region. *Bothrionia subpusillus* (Licharew) appears to be a somewhat smaller species and still more transverse.

*Bothrionia nasuta*, new species

PLATE 316: FIGURES 1-26; PLATE 317: FIGURES 1-10

*Productus texanus* R. E. King (not Girty), 1931:89, pl. 23: fig. 7.

Small, subtriangular to semielliptical outline; widest at hinge, commonly alate; ears large, usually acute; sides gently rounded, sloping strongly medially. Anterior margin, when complete, narrowly nasute, drawn to small half tube, or trough. Surface irregularly costate, costae subdued, frequently discontinuous, numbering three to four per 5 mm on trail. Spines slender, full length not known: one on each ear near distal angle; row of three at base of lateral slopes; horizontal row on trail at about level of anterior end of sulcus; scattered small and delicate spines on visceral disc and trail rarely preserved.

Pedicle valve with fairly even lateral profile, venter strongly convex, posterior third somewhat less so, anterior third or trail gently convex. Anterior

MEASUREMENTS (in mm).—*Bothrionia nasuta*, new species:

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706b							
149637a	15.5	13.0	25.0	17.2	15.3	8.1	3.2
(holotype)							
149637b	14.5	?	25.0	16.2	14.0	7.8	2.9
149637c	13.3	11.2	21.0	15.6?	14.4	7.0	2.9
149637d	14.1	?	24.0	16.0	14.3	7.9	?
149637e	13.3	10.9	22.0	15.7	14.5	7.0	2.6
149637f	11.5?	9.0	18.0	16.7	13.9	5.8	1.8
149637g	12.8	?	20.0	16.8	14.9	6.1	?
149637h	15.2	?	26.0	19.5	16.7	7.8	?
USNM 713							
149639	16.2	?	24.0	16.8	14.9	8.2	?
USNM 706							
149635a	15.4	?	25.0	18.1	16.2	8.0	?
159635b	16.0	?	30.0	18.8	15.6	8.4	?
159635c	?	?	?	18.1	?	?	2.9



profile broadly domed, with sloping sides. Beak small; umbonal region swollen moderately, not projecting far posterior to posterior margin. Sulcus shallow, originating on anterior slope of umbonal region and extending anteriorly part way on trail, then ending abruptly in flattened area, becoming narrow trough at anterior margin. Costellae bounding sulcus commonly sloping medially to terminate on anterior part of sulcus; one or two costellae in sulcus, but arrangement not regular. Anterior margin of trail forming band with closely crowded costellae. Flanks bounding sulcus moderately rounded, lateral slopes steeply inclined. Ears broad, commonly alate, gently convex.

Brachial valve delicate and thin, fitting closely into concavity of pedicle valve, thus forming thin visceral cavity. Maximum concavity at midvalve. Umbonal region deeply concave; fold originating near posterior quarter and occupying about median one half; anterior extremity probably with narrow trough (not preserved). Ears broad and concave, defined by broad, oblique flexure. Sides and anterior steeply sloping. Costellae more subdued than on pedicle valve.

Pedicle valve interior with small, narrowly and transversely elliptical diductor scars. Adductor scars inserted in pit in thickened specimens; ear baffles moderately strong but continued around margin of visceral disc as thick ridge. Inner spines prominent.

Brachial valve interior with moderately thickened posterior platform; small cardinal process and small adductor scars. Endospines long, slender, and forming thick band.

**STRATIGRAPHIC OCCURRENCE.**—Word Formation (China Tank and Willis Ranch members and lens above the latter).

**LOCALITIES.**—China Tank: USNM 706c, 713, 726r. Willis Ranch: USNM 706. Lens: USNM 706b.

**DIAGNOSIS.**—Small, compact, triangular *Bothrionia* with strong costae, midwidth and length nearly equal.

**TYPES.**—Holotype: USNM 149637a. Figured paratypes: USNM 149635a, b, 149636a, b, 149637b, f, 149639, 153845. Measured paratypes: USNM 149635a-c, 149637b-h, 149639. Unfigured paratypes: USNM 149637c-e, g, h.

**COMPARISONS.**—This species is similar in form and outline to *B. pulchra*, new species, but the Guadalupe species is less strongly costate, the ears are more accentuated by steeper umbonal slopes, and the ears

are enclosed on the outside by a prominent elevation. The other described species from Texas are larger and relatively more transverse than *B. nasuta*.

### *Bothrionia pulchra*, new species

PLATE 317: FIGURES 11–18

Shell small, subtriangular outline, hinge forming widest part; anterior margin narrowly nasute. Sides slightly convex and sloping strongly toward middle. Umbonal and visceral disc regions costate, costae made nodose by rounded spine bases; trail marked by closely crowded costae forming band around anterior half. Spines one on each ear, row of three at base of lateral slopes, band around midvalve just posterior to costate band of trail.

Pedicle valve moderately convex, umbonal region somewhat flattened but more abruptly bent from venter, trail gently convex, forming long steep slope. Sulcus narrow and shallow, occupying midvalve, passing anteriorly into narrow half tube projecting anterior to margin. Flanks rounded and steep; midvalve strongly swollen. Ears flattened and well demarcated from precipitous umbonal slopes.

Brachial valve deeply concave, umbonal and visceral regions forming circular depression, deepest medially; sides short, sloping moderately; ears with elevated outer rim, demarcated on inside by abrupt descent to midvalve. Surface completely costate and with dimples in interspaces except on part corresponding to closely and regularly costate trail. Fold narrow but obscure.

Pedicle valve interior with lightly developed rim around visceral region. Brachial valve interior unknown.

**MEASUREMENTS** (in mm).—From locality USNM 732, holotype 149631: Length 14.2, brachial valve length 11.0, surface length 22.0, hinge width 16.6, midwidth 15.4, height 7.5, thickness 2.2.

**STRATIGRAPHIC OCCURRENCE.**—Cherry Canyon Formation (Getway Member).

**LOCALITIES.**—AMNH 496, 519, 600; USNM 730, 732.

**DIAGNOSIS.**—Small, triangular *Bothrionia* with short sulcus and strongly nasute anterior but costae not strong.

**TYPES.**—Holotype: USNM 149631. Figured paratype: USNM 149630.

**COMPARISON.**—This species in size and shape is

similar to *B. nasuta*, new species, but it is less strongly costate than the Glass Mountain species. Its sulcus is somewhat shorter than that of *B. nasuta* and the narrow, troughlike fold of the anterior margin is longer although it does not protrude beyond the anterior margin any farther than in *B. nasuta*. The ears of *B. pulchra* are more prominent than those of *B. nasuta* because the umbonal slopes of the former are steeper and the surface of the ear is depressed along the bases of the umbonal slopes.

***Bothrionia transversa*, new species**

PLATE 317: FIGURES 19–54; PLATE 318: FIGURES 27–57

*Marginifera? texana* R. E. King (not Girty), 1931:89, pl. 23: figs. 5–7.

Large for genus, wider than long, outline semi-elliptical to subrectangular. Ears large, commonly alate. Sides sloping medially; anterior margin gently rounded to subnasute. Surface irregularly costate,

costae variable in size, ranging from three to four per 5 mm on median level of trail. Spine arrangement as described for genus.

Pedicle valve moderately convex in lateral profile, posterior third gently convex, anterior third forming moderately sloping trail; venter swollen and narrowly convex. Sulcus poorly defined, shallow, originating on posterior side of venter and terminating posterior to anterior margin in broad, flattened band of finer and crowded costellae. Flanks rounded, not prominent; lateral slopes fairly steep.

Brachial valve concave, sides short; deepest medially, ears set off by oblique fold. Fold inconspicuous. Brachial ornament subdued.

Pedicle valve interior with small ear baffles and lightly developed ridge around visceral area. Muscle field slightly impressed.

Brachial valve interior generally delicate but strongly thickened in old shells. Curvature moderate, and posterior platform moderately thickened, except in old shells. Endospines numerous and long.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 715i							
149646a	16.3?	?	26.0	22.4	19.0	8.2	?
149646b	15.9	13.1	27.0	22.1	19.6	9.0?	4.0
149646c	15.1	?	23.5	21.9	19.7	6.6?	?
149646d	14.2	?	24.0	21.9	17.8	7.0	?
149646e	14.3	?	24.0	21.3	16.9	7.6	?
149646f	13.1	?	21.0	21.6	17.4	6.8	?
149643	16.4	12.0	25.0	21.9	19.3	8.5	3.0
(holotype)							
USNM 706b							
149641a	16.9	?	27.5	22.0	18.9	8.9	?
149641b	15.0	?	25.0	22.3	18.6	8.0	?
149641c	14.1	11.8	23.0	22.3	18.7	7.2	?
149641d	13.3	11.5	22.0	20.7	17.4	7.1	?

STRATIGRAPHIC OCCURRENCE.—Word Formation (Willis Ranch and Appel Ranch members and lens between them).

LOCALITIES.—Willis Ranch: USNM 706e. Lens: USNM 706b. Appel Ranch: USNM 715i, 719z, 722t, 727j.

DIAGNOSIS.—Widely transverse *Bothrionia* with strong and sharply incised costae.

TYPES.—Holotype: USNM 149643. Figured para-

types: USNM 149641a, c; 149646b, e, h; 153846; 153848a-e; 153849a-c; 153850a, b. Measured paratypes: USNM 149641a-d, 149646a-f. Unfigured paratypes: USNM 149641b, d; 149646a, c, d, f, g. Figured specimen: YPM 11733.

COMPARISON.—Of described species this one can be compared to *B. guadalupensis*, new species, which is also strongly transverse. The Glass Mountains species is more strongly ornamented and the re-

relationship of midvalve to length shows the species to be more transverse at midvalve than the Guadalupe species.

### Genus *Costispinifera* Muir-Wood and Cooper, 1960

*Costispinifera* Muir-Wood and Cooper, 1960:217.—Williams et al., 1965:H479.

Small, length and width nearly equal, deeply concavo-convex, subquadrate outline; hinge wide, generally forming greatest shell width; anterior commissure slightly uniplicate. Visceral cavity deep. Both valves intricately wrinkled in young stages but finely costate in adults. Halteroid spines prominent on ears; ornament spines scattered over whole surface, but on pedicle valve arranged in rows following costae. Ornament spines short and curved. Costae discontinuous, generally confined to trail and lateral slopes. Brachial valve costate on anterior reflected part and strongly spinose over entire surface, spines of ears and lateral margins larger and usually narrowly curved toward midvalve.

Pedicle valve flattened umbonally, narrowly rounded at place of geniculation, trail long. Trail and geniculated region marked by moderately deep sulcus. Adductor field elongated, moderately thickened; diductor scars flabellate. Posterior margin with narrow ginglymus. Ears with striated baffle. Anterior slope with stout endospines.

Brachial valve interior with prominent ears; adductor field thickened, consisting of two elongate inner scars usually thick and prominent, and two outer inconspicuous scars; brevisseptum short. Lateral ridges poorly developed; brachial ridges often extravagantly thickened. Cardinal process with elongate and posterodorsally folded median lobe; shaft short and myophore rounded, lophidium small, carinate. Long endospines occupying interior near where trail deflects from visceral area.

**TYPE-SPECIES.**—*Costispinifera costata* (R. E. King, 1931:85, pl. 21:figs. 8–13) senior synonym of *C. texana* Muir-Wood and Cooper (1960:218, pl. 67:figs. 1–17).

**DIAGNOSIS.**—Partly costate and partly rugose *Costispinifera* with both valves strongly spinose.

**COMPARISON.**—*Costispinifera* may be confused with several members of the same subfamily. Young of *Echinauris* may be mistaken for the young of *Costispinifera*, but specimens of the former are not strongly rugose, as are the young of *Costispinifera*.

Adults of the two cannot be readily mistaken, because *Echinauris* Muir-Wood and Cooper has much longer ear spines and it is not anteriorly costate. The nonspiny ears and generally stronger costation and less numerous spines serve to distinguish *Liosotella* Cooper from *Costispinifera*. In general appearance, *Elliottella* Stehli is almost exactly like *Costispinifera* but it does not have spines on the brachial valve. Other members of the subfamily are strikingly different, and confusion of them with *Costispinifera* is unlikely.

**DISCUSSION.**—A few details of the genus should be discussed because some of them might be confusing to students unfamiliar with productids. The exterior of *Costispinifera* is its most distinctive character and is quite complex; furthermore, like that of most other productids it is variable. The visceral region of old shells and the entire surface of youthful specimens having a length of 10 mm or less are strongly rugose. This feature is variable but where it is best developed it consists of narrowly rounded and fairly regular concentric rugae. These rugae are regular in their size but not in their course over the shell, because they are wavy where they pass around spine bases. In some specimens the rugae are regular and give an attractive pattern underlying the spines. In the majority of specimens, however, the pattern is obscured by irregularities in growth, accidents, or the wear to which a shell is subjected in the sea.

Costae are not developed in conjunction with the rugae but appear just anterior to them and are entirely a feature of the anterior slopes, or trail. These are variable; most specimens have them fairly well developed, but in some their development was postponed until late stages of trail formation. In some specimens, furthermore, they are nearly continuous but in others, they appear to be interrupted and discontinuous. In these they suggest elongate spine bases, because the trail spines are wholly confined to the costae. The brachial valve costae are generally confined to the geniculated or reflected part of the valve that forms the short trail.

Although the spine arrangement is variable in detail, it follows a fairly definite pattern throughout the members of the genus. Spines of the pedicle valve are clearly divisible into two kinds: halteroid, or steadying, spines and ornament spines, which also probably play a minor role in steadying the

specimens on the sea bottom or anchoring in mud. The halteroid spines appear low on the lateral slopes and generally hang over the ears. Halteroid spines are few on the posterior margin and many specimens have none on the ears. Although a fair number of specimens have spines scattered on the ears, they are seldom numerous and usually not large. The longest halteroid spine measured is 20 mm and this was about equal to the length of the shell. These halteroid spines are not generally well preserved and no perfect specimens appear in the collection. The halteroid spines make a conspicuous tuft on each side of the shell. They are readily distinguished from the ornament spines because they are fairly straight and extend laterally and posterolaterally, whereas the other spines are curved anteriorly.

Most ornament spines appear to be short and taper distally. They are given off from a costa on the trail and are stouter at the base. They remain open but taper toward the free end. In some specimens the point of appearance of a spine is also the place of origin of a costa or part of one. Many spines are buttressed anteriorly by a costa that may extend to the margin or recede before reaching another spine base in line with it. In many specimens, however, many costae are continuous and the spines appear at a few or many points along the costa. The anteriormost spines, those that overhang the anterior margin, appear somewhat longer than those on the main part of the trail and thus may play a role in steadying the specimen if it lies on the bottom, and may have served a protective function as the shell gaped.

Young specimens, and the older parts of the visceral disc, have short spines curved and tapering that arise from inconspicuous, rounded bases. Infrequently, a short radial extension of the base may be noted, but this is usually interrupted by the concentric rugae. The radial element does not become conspicuous until the shell starts to geniculate or change its general direction of growth. On the visceral region no definite alignment of spines can be discerned, whereas on the trail, they are radial, but no lateral alignment is clear on this part.

The ornament of the brachial valve has all the elements of the opposite valve, and, in addition, many scattered pits or dimples that appear to be complementary to some of the spine bases of the pedicle valve. The visceral region of this valve is

usually strongly rugose, and the anterior geniculated, or deflected, part of the valve, which forms an anterior rim, is costate. The surface is covered by a veritable forest of fine spines of two sizes; those occupying the median parts are fine and hairlike, arising at an angle approaching 90° and usually curved toward the anterior; those on the posterior and anterior margins and on the ears are larger than those more medially placed, and commonly are abruptly curved medially. The spines on the ears and posterolateral slopes extend inward and lie over the umbo and the finer spines of the median region. Spines on the anterolateral and anterior borders may extend inward or outward with no apparent plan.

The beak of the pedicle valve of *Costispinifera* is very small and the region around it is only slightly swollen. The beak hangs slightly over the delthyrium, which is wide and indistinct. The ginglymus is a curved notch located in the adventitious shell just under the posterior margin on each side of the delthyrium. Laterally it extends to near where the ears become prominent. This narrow groove receives the posterior edge of the brachial valve which rotates in it. When more elaborately developed than in *Costispinifera*, it may be mistaken for an interarea. It is especially well developed in the Dictyoclostidae.

The ear is a prominent feature of both valves of *Costispinifera*. In the pedicle valve it is less extended but is narrowly rounded and concave, forming a small trough. The ear is demarcated from the visceral cavity by an oblique ridge or small shelf. The inner, or ventrad, margin of the ridge is marked by oblique striae and ridges that suggest that the hollow ear is a water channel for the feeding animal, as in *Marginifera* (Grant, 1968). These striae and ridges extend under the ears and along the inner valve wall to about midvalve in some specimens.

Another feature of the interior of the pedicle valve is the scattered endospines, the purpose of which is not entirely clear. These may be as much as 1 mm long and may lie prone against the inner surface or may project at a high angle to the surface. The latter high-angle spines are usually short. Most endospines are hollow and are open at the free end. The spines are most numerous on the side walls under the ears and are rare or less numerous in the median part of the valve. These spines appear to be

located in areas where incurrent streams are likely to be strongest.

The exterior sulcus creates an interior median fold or ridge on which the adductor field is located. This ridge elevates the muscle scars, and when these are thickened they have the appearance of a long narrow platform. The scars are thickened only in the older shells, which appear to have an extremely long anterior pair and a much shorter posterior pair.

Inside the brachial valve the ear, like that of the opposite valve, shows evidence of having shared in directing water currents into the mantle cavity. The brachial valve ear is somewhat narrowly rounded, more extended than that of the other valve, and is separated from the visceral area by an oblique groove. The side of this groove toward the anterior is marked by short, oblique ridges and grooves like the area just below the ear-ridge of the pedicle valve. This side of the groove has left a fairly distinct growth track in the form of a low ridge traceable to a point near the cardinal process.

The cardinal process is short-shafted and in some specimens seems almost nonexistent. The myophore is swollen, rounded, and deeply grooved on its ventrad side. The groove in some is so deep as to be regarded as a pit. The median lobe of the myophore bearing the groove or pit is folded in a dorsal direction and tapers distally. It is usually fitted snugly between the two lateral lobes of the myophore, which are flattened laterally and, in some specimens, nearly meet behind the median fold. The cardinal process thus comes to have a trilobed appearance in posterodorsal view, the meeting lobe consisting of the folded part bearing the median groove and the lateral lobes bounding slits that must have been occupied by the muscle fibers. In old specimens, the myophore, except for the median folded part, is not visible when the shell is viewed from the interior.

Near the base of the cardinal process the shell is thickened on each side by short ridges which form a broad V. Seen from the posterior these form a low platform on which the cardinal process rests. The beak of the brachial valve is deflected a short distance dorsally. The space between the posterior margin and the myophore is occupied by a narrow lophidium. At the base of the lophidium is an indistinct pit which receives the posterior angle of the delthyrium and helps to articulate the valves.

The lophidium fits closely under the small beak of the pedicle valve and makes the union of the two valves snug. Lateral ridges are not developed to a noticeable extent in this genus.

The adductor field of the brachial valve of *Costispinifera* is thickened into a definite adductor platform. Both adductor scars are elongate, but the inner scars are somewhat teardrop shaped. The outer scars wrap around the posterolateral margins of the inner scars and are thus long and slender in some specimens; in others they occupy the same position but are fairly straight. The brachial ridge, as usual, originates between the inner and outer adductor scars, then extends directly laterally to the place where the anterior slope starts, makes a loop parallel to the edge of the slope, and then is narrowly looped to terminate at midvalve, well outside the outer edge of the adductor field.

The line marking the origin of the anterior slope is occupied by long endospines which decrease in size posterolaterally and terminate near the groove separating the ears and the visceral region. Some endospines are 2.5 mm long.

**GROWTH.**—The smallest specimen assignable to this genus measures about 2.5 mm in length and width. Up to about 5 mm the young have their length and width about equal. Specimens of this size and up to 10 mm, when well preserved, are usually provided with an attachment ring on the umbo of the pedicle valve. This may consist of one or more sets of spines curving up from the umbo to surround a small round object such as the spine of a parent or a small crinoid stem. Above 5 mm in length the growing shell begins to widen until it reaches maximum width, after which, it grows anteriorly without significantly widening. The lengthening of the trail is accomplished in a broad curve.

Below 5 mm the brachial valve has no spines, no median septum, and the cardinal process is distinctly bilobed with the myophore in a primitive state. Between 5 and 10 mm this valve starts to develop spines, the median septum appears, and the median lobe of the cardinal process develops and is essentially adult before a length of 10 mm is reached.

**STRATIGRAPHIC OCCURRENCE.**—*Costispinifera* appears to be confined to the Word Formation and its equivalents. In the Glass Mountains it appears in the China Tank Member but is very abundant in the lower part of the Willis Ranch Member. It is



the commonest productid at USNM 706, and there the preservation is superb. In the higher parts of the Willis Ranch Member it is extremely rare. It is also a rare shell in the Appel Ranch Member. In the Guadalupe Mountains it occurs in the Getaway Limestone Member of the Cherry Canyon Formation, but is not common. In the Delaware Mountain Formation in the southern part of the Delaware Mountains, Girty (1909:269) reported a species of it as occurring in "considerable abundance."

*Costispinifera costata* (R. E. King)

PLATE 320: FIGURES 1-44, 45-51?; PLATE 321: FIGURES 10-29

*Avonia walcottiana* R. E. King (not Girty), 1931:85, pl. 21: figs. 1-4.

*Avonia walcottiana costata* R. E. King, 1931:85, pl. 21: figs. 8-13.

*Costispinifera texana* Muir-Wood and Cooper, 1960:218, pl. 67: figs. 1-17.

Medium size, hinge wide, ears prominent outline subquadrate; sides deeply indented anterior to ears but strongly rounded anteriorly; anterior margin broadly rounded and medially indented. Anterior commissure faintly uniplicate. Spines on both valves, numerous and slender. Costae variable, usually in excess of 20 and ranging to 26.

Pedicle valve unevenly convex in lateral profile, anterior two-thirds, or trail, moderately convex but

posterior third narrowly rounded, curvature great enough to bring surface of umbonal region approximately parallel to surface of trail at its maximum curvature. Anterior profile strongly domed, with precipitous sides and indented middle. Umbonal region projecting about one-third length posterior to hinge line, flattened, small pointed beak projecting slightly beyond hinge-line. Umbonal slopes moderately steep; geniculated region greatly swollen. Trail and anterior slope long and rounded. Sulcus originating near place of geniculation or slightly anterior, shallow and broadly U-shaped, extending to anterior margin, here forming slight indentation. Flanks bounding sulcus rounded and with steep slopes. Ears triangular, convex, protruding beyond midwidth.

Brachial valve deeply and evenly concave, maximum cavity near midvalve; ears deflected ventrally, flattened to slightly concave, set off from rest of valve by low, oblique ridge; fold originating near midvalve, low and indistinct. Umbonal region forming shallow concavity.

Pedicle valve interior with prominent ridge separating ears from visceral region; adductor field long and slender, moderately thickened in adults and old shells; endospines numerous, especially on lateral walls.

Brachial valve interior with strong ear ridge, stout and somewhat bulbous cardinal process, small median septum, but long and stout endospines. Brachial ridge well developed only in old specimens.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width*	midwidth	height	thickness
USNM 706							
124150a	21.9	21.9	13.8	45.0	22.3	14.0	7.5
149703a	16.3	12.9	32.5	19.6	18.8	10.8	6.6
149703b	14.5	11.6	23.0	15.1	16.0	9.7	6.6
149703c	12.0	10.9	18.5	8.6	14.0	4.8	2.7
149703d	20.7	14.7	35.0	27.6	22.7	12.5	6.8
149703g	17.0	12.6	34.5	19.4?	19.0	11.7	7.7
149703j	13.3	12.1	25.0	14.4	15.7	8.2	4.5
149703l	12.7	11.1	22.0	13.6	14.8	7.0	4.0
149703p	19.0	12.0	38.0	20.0	20.6	12.0	6.6
149703w	10.8	9.6	16.5	7.7	12.3	5.2	3.5
149703x	9.0	8.4	12.0	6.2	10.5	3.4	1.6
149704a	6.3	5.8	8.0	6.1	7.8	2.2	1.2
149704b	5.5	4.8	6.0	3.9	5.4	1.6	1.1
149704c	4.8	4.4	5.0	3.4	4.7	1.5	1.2

\*Ears on all specimens damaged; hinge width approximate.

STRATIGRAPHIC OCCURRENCE.—Word Formation (Willis Ranch Member and lens between Willis Ranch and Appel Ranch members).

LOCALITIES.—Willis Ranch: AMNH 506; USNM 704, 706, 706e, 718d, 723w, 724u, 731u. R. E. King T240, 241. Lens: USNM 706b.

DIAGNOSIS.—*Costispinifera* with numerous fine costae.

TYPES.—Lectotype: T10282a. Figured paratypes: T10282b-f, YPM 11568. Figured hypotypes: USNM 124150a, b; 124151b, c; 149702a-e; 149703a, b, d, i, o; 153864a, c-g; 153871a-c; 153872a-f. Measured hypotypes: USNM 124150a, 149703a-d, g, j, l, p, w, x; 149704a-c. Unfigured hypotypes: USNM 124151a; 149703c, e-h, j-n; 153864. Figured specimens: USNM 153865, 153866, 153867.

COMPARISON.—Differs from *C. rugatula* (Girty) by its finer costation, finer spines, and larger, more extended, ears.

DISCUSSION.—This is a very abundant species in the lower part of the Willis Ranch Member. Much of the information in the discussion of the anatomy under the genus was derived from this species. King's cotypes are from the Willis Ranch Member in the hill north of Leonard Mountain. Although all of his specimens are greatly decorticated, it is necessary to select a type specimen from them. We choose specimen T10282a (R. E. King 1931, pl. 21: figs. 10a,b) to be the type of the species because it best preserves the shape, beak, both profiles, and a suggestion of the ears.

Restudy of King's and Girty's specimens makes it necessary to put into synonymy *C. texana* Muir-

Wood and Cooper. Comparison of silicified and decorticated specimens often leads to many difficulties of recognition.

### *Costispinifera rugatula* (Girty)

PLATE 310: FIGURES 62-70; PLATE 312: FIGURES 21-24; PLATE 319: FIGURES 1-56; PLATE 321: FIGURES 1-9

*Productus subhorridus* var. *rugatulus* Girty, 1909:267, pl. 30: figs. 11-12c.—R. E. King, 1931:84, pl. 20: figs. 12, 13, 15.

*Costispinifera* having essentially same outline and profiles as *C. costata* but differing in several anatomical features and details of ornament. Umbonal and visceral regions of both valves marked by narrow, elevated concentric lines to place of geniculation; there concentric ornament displaced by strong, irregular costellae, variable in development, some specimens having continuous costellae but in others these appearing on anterior side of spine, and interrupted. Ornament spines moderately long and curved, stout; halteroid spines long and stout. Brachial valve strongly marked concentrically in visceral region and deeply pitted. Pits crudely arranged radially and anteriorly occupying spaces between costae.

Pedicle valve with moderately deep sulcus extending from place of geniculation to slightly indented anterior margin. Ears moderately developed. Brachial valve deeply concave, maximum concavity near midvalve; umbo forming deeply concave pit.

Brachial valve interior with thick adductor platform and stout endospines.

#### MEASUREMENTS (in mm).—*Costispinifera rugatula*, new species:

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706c							
149715a	22.7	15.0	?	23.2	20.9	13.0	8.8
149715b	17.7	14.4	34.0	18.0?	20.0	12.2	7.1
149715c	18.2	14.3	37.0	19.9	20.6	13.0	8.4
149715d	15.6	12.4	30.5	18.3	17.8	10.9	7.0
149715e	14.1	11.0	28.5	18.6	16.8	9.5	6.0
149715f	13.6	11.1	26.0	14.3	15.5	9.1	5.1
149715g	12.6	11.3	19.5	10.4	14.6	6.2	3.7
149715h	9.7	8.7	16.0	7.5	10.8	4.4	2.4
149715i	8.8	7.9	12.5	7.6	10.0	3.1	1.4
149715j	6.1	5.5	7.5	4.5	7.0	1.9	1.0
149715k	4.5	4.2?	5.5	3.3?	4.8	1.7	0.7

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation, Word Formation (China Tank Member, and lens between Willis Ranch and Appel Ranch members).

LOCALITIES.—Road Canyon: USNM 706f, 713, 716xa, 721j, 724b, 732j. China Tank: USNM 706c, 726r, 731m, 732s, 733q. Lens: USNM 706b.

DIAGNOSIS.—Like *Costispinifera costata* (R. E. King) but with stronger costation, more discontinuous costae, stouter spines, and larger pits in the brachial valve.

TYPES.—Holotype: USNM 118536a. Figured paratype: USNM 118536b. Figured hypotypes: USNM 149708a-e; 149715 a, c, e-j; 153862a-c; 153863 a-d, f; 153868d, g; 153869; 153870a, b; 153878a, b; 153905. Measured hypotypes: USNM 149715a-k.

COMPARISON.—This species has a slight overlap with *C. costata* because the more numerous costate members strongly suggest some of the more coarsely costate members of that species. Generally, however, it is usually easy to distinguish the two species even though their size and shape are almost identical. *Costispinifera rugatula* is more strongly ribbed than *C. costata* in all stages of growth and, furthermore, its spines are much stouter than those of the younger species. Another point of distinction is the smaller and less extended ears of *C. rugatula*. They are pointed but are seldom extended laterally like those of *C. costata*.

Girty's type lot consists of two specimens, one complete with brachial valve but the other a single pedicle valve. Unfortunately, both specimens are young forms having the pronounced concentric wrinkles that characterize the young stages of this genus. They are also more sparsely costate anteriorly and have more scattered spines than many of the adult specimens.

### *Costispinifera walcottiana* (Girty)

*Productus walcottianus* Girty, 1909:269, pl. 21: figs. 27, a, b [not 28]. [Not *Avonia walcottiana* King, 1931:85.]

Small, wider than long, outline subquadrate; sides rounded; anterior margin indented; lateral profile strongly convex, gently convex visceral region and long moderately convex trail. Beak small; umbo narrowly convex, steep slopes to ears. Place of geniculation narrowly rounded. Sulcus fairly deep and moderately wide, originating near

middle of visceral area. Flanks bounding sulcus narrowly rounded and with steep lateral slopes. Visceral region marked by strong, wavy concentric rugae and scattered, rounded spine bases. Trail marked by interrupted costae, strongest on anterior side of spine bases. Costae ending abruptly near midpoint of rounded geniculated area. Ears not preserved. Spines, as indicated by bases, fairly stout.

MEASUREMENTS (in mm).—Holotype: length 12.1, surface length 25.0?, hinge width 13.0?, mid-width 17.1, height 10.0.

STRATIGRAPHIC OCCURRENCE.—Delaware Mountain Formation (700 feet above the basal black limestone) according to Girty (1909) but assigned to the Getaway Limestone Member, Cherry Canyon Formation, by Newell, et al. (1953).

LOCALITY.—USGS 2903 (green).

DIAGNOSIS.—Compressed *Costispinifera* with width considerably greater than length, strongly costate trail and strongly wrinkled visceral region.

TYPES.—Holotype: USNM 118537.

COMPARISON.—This species differs from *Costispinifera costata* (King) in its greater proportional width, less numerous costae, and compressed profile.

DISCUSSION.—Girty based this species on two specimens, one, the holotype, from the Delaware Mountain Formation (Getaway Limestone Member of the Cherry Canyon Formation) and the other, USNM 118538, on a filling of the interior of the pedicle valve, found on the side of the road opposite from USGS 2903 in Gualalupe Canyon. It is impossible to be sure that the two are the same. King (1931: 85) believed with Tschernyschew (1916) that they are not the same and placed the internal mold in the subspecies *A. walcottiana costata*. It is doubtful that this specimen should be assigned there, consequently at the present time it fits in none of the accepted categories. It is also impossible to identify the abundant and well-preserved Glass Mountain species with Girty's specimen. A suite of specimens is greatly needed to establish the true specific characters of *C. walcottiana*.

### Genus *Elliottella* Stehli, 1955

*Psilonotus* Stehli, 1954:323. [Not of Walker, 1834, insect.]  
*Elliottella* Stehli, 1955:711.

Usually small, transversely rectangular, squarish

to subcircular outline; hinge usually equal to or greater than midwidth; ears commonly large and conspicuous; anterior commissure usually with narrow fold in dorsal direction (uniplicate). Pedicle valve strongly convex; brachial valve deeply concave, with thin visceral chamber. Pedicle valve exterior with fairly strong concentric wrinkles in visceral disc region; venter and trail strongly but irregularly costate; halteroid and ornament spines scarcely differentiated, given off from costae; ornament spines long and curved anterodorsally; halteroid spines directed anterolaterally and posteriorly, those on lateral slopes arranged in crudely curved rows. Brachial valve concentrically rugose in visceral and posterolateral regions, trail costate and with dimples corresponding to spines of pedicle valve on visceral disc and slopes; no spines on brachial valve.

Pedicle valve interior with elongate adductor scars located on internal ridge produced by external median sulcus; ear baffles strong, striated, commonly continued as ridge inside lateral margins in old shells; interior spine bases on lateral slopes.

Brachial valve interior with small, sessile, marginiferid cardinal process; myophore small; lophidium small; lateral ridges joining striated ear baffles. Adductor field elongate, scars teardrop-shaped; brevisseptum delicate; endospines small, on narrowly rounded geniculated area. Brachial ridges as usual for Costispiniferidae.

TYPE-SPECIES (by original designation).—*Psilonotus transversalis* Stehli (1954:323).

DIAGNOSIS.—Anteriorly costate Costispiniferidae irregularly spinose, without spines on brachial valve, and with small lophidium.

COMPARISONS.—*Elliottella* suggests *Costispinifera* at first glance but exterior features of the two genera, such as the costation and spines of the pedicle valve, are really quite different. The costae of *Elliottella* are strong and continuous, while those of *Costispinifera* are usually narrow and interrupted, and are usually shorter than those of *Elliottella*. Another important difference between the two genera is the abundance of spines on the brachial valve of *Costispinifera* and their absence from that valve of *Elliottella*.

*Desmoinesia* Hoare might be confused with *Elliottella*, but it has a spinose brachial valve and the costellae of both valves are more regular and finer than those of *Elliottella*. Interior differences

between *Desmoinesia* and *Elliottella* are the presence of a thickened rim on the margin of the pedicle valve of *Desmoinesia* and its absence in *Elliottella*, the strongly endospinose interior in the midregion of *Desmoinesia*, and the absence of a lophidium in the same genus.

*Elliottella* differs from *Echinauris* Muir-Wood and Cooper in not having spines on its brachial valve and in having a strongly costate trail.

*Hystriculina* Muir-Wood and Cooper and *Elliottella* strongly resemble one another but the former has only a few scattered spines, fairly regular and weak radial ornament, and a feebly developed marginal ridge, the last a feature not usually present in *Elliottella*.

DISCUSSION.—Because of the nondescript nature of the spines and the general similarity to other anteriorly costate genera having small shells, *Elliottella* is not an easy genus to recognize, and recognition becomes even more difficult in poorly preserved or nonsilicified material.

No definite pattern or plan has been discerned in the arrangement of the spines. The anterior ornament spines appear to have been as long as the halteroid spines, but they are strongly curved anterodorsally and at the front margin they hang over the dorsal valve. Small halteroid spines appear on the posterior margin and occasional ones on the ears. The costae on the trail are generally strong and elevated, with fairly deep grooves between. A few of them appear to originate with a spine, but most of them are present on the venter and bear several spines.

The ears of both valves are prominent. On the pedicle valve they are moderately rounded in section and moderately concave on the interior. Those of the brachial valve are moderately rounded internally but somewhat flattened on the exterior. Baffles across the ears are fairly well developed in both valves. In old pedicle valves the striated baffle is continued laterally along the inside of the lateral margin, but it usually dies out near midvalve or slightly beyond. The same is true of the brachial valve. A ridge extends laterally from the base of the cardinal process, then extends obliquely to join the ear baffle. In some of the older specimens it is extended for a short distance beyond midvalve, where it dies out.

Inside the pedicle valve few features can be determined with certainty in the type species. The

adductor field is seldom thickened to a notable degree. The lateral slopes just ventrad of the ear baffle generally are marked by a row of elongate slits, or holes, with thickened rim. These represent the points of entry of the spines forming the outermost row on the outside of the lateral slopes. Each hole generally can be linked to a spine on the exterior. The slitlike form of some of them may indicate that they are being gradually closed by the mantle.

The cardinal process of *Elliottella* is typically marginiferid and shows no exceptional features. It is generally nearly sessile, but most specimens build up at its base a thickening or platform that may protrude slightly beyond the posterior margin. The inner adductor pair is generally easily visible and is commonly thickened to some extent but rarely considerably thickened. The region between the posterior end of the adductors and the anterior end of the cardinal process is somewhat thickened generally, but exceptionally becomes rounded and ridgelike, uniting with the thickened brevisseptum. The latter is generally thin and delicate and is commonly so badly worn as to be visible only with difficulty. When well preserved, it is bladelike and has a steep anterior edge.

Brachial ridges are usually present but are commonly obscure and incomplete. When well preserved, the outside margins of the loops overlap on the inner rim of endospines. The region occupied by the endospines is very convex and fits snugly into the inner part of the venter of the pedicle valve. The endospines are moderately large and form a narrow patch where the visceral disc passes into the anterior slope or trail.

**GROWTH.**—*Elliottella* is another of the genera that attached by rings of spines at the umbo in its youthful stages. The most youthful forms are nearly circular in outline, with one or two rings, usually with strongly rugose valves and a few spines of considerable length, commonly longer than the valve length. A specimen about 3 mm in diameter has 5 spines on each side of the midline. Another 4 mm long by 4.5 mm wide has 8 spines on the body and 2 on the posterior margin on each side of the umbo. At an early age, before attaining 3 mm in length, the shells are generally definitely wider than long. They are flatly convex. The development of strong convexity is a variable feature.

### *Elliottella minima* (Stehli)

PLATE 323: FIGURES 1–24

*Psilonotus minimus* Stehli, 1954:324, pl. 22: figs. 17–19.

This species is generally smaller than the other two in the Sierra Diablo and is characterized by stronger, more crowded costae; the majority of the specimens maintain this strong costation, especially in adulthood. Measurements are given below for comparison with those of *Elliottella multicostata*, new species, and *E. transversalis* (Stehli).

**STRATIGRAPHIC OCCURRENCE.**—Bone Spring Formation, Skinner Ranch Formation.

**LOCALITIES.**—Bone Spring, AMNH 625, 631; USNM 728e, 728f, 745. Skinner Ranch: AMNH 520.

**TYPES.**—Stehli designated two syntypes and a number of paratypes. The syntypes were, undoubtedly, his leading specimens. Consequently we select

#### MEASUREMENTS (in mm).—*Elliottella minima* (Stehli):

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 728e							
152707a	12.7	10.3	25.0	14.2	15.3	8.8	5.0
152707b	12.3	10.2	23.0	16.0	14.4	8.4	3.4
152707c	11.9	9.4	21.5	13.0	13.4	7.5	4.6
152707d	11.6	9.4	20.5	15.0	15.0	8.0?	2.8
152707e	10.5	8.8	19.5	12.3	13.2	6.5	3.2
152707f	10.4	8.5	17.5	13.5	14.1	5.7	1.8
152707g	10.4	8.7	16.0	11.4	13.7	5.5	3.0
152707h	9.4	7.9	16.0	10.0	12.1	5.5	2.1
152707i	8.5	6.7	14.0	8.4	10.5	4.8?	2.1



one of these, the pedicle valve AMNH 27306/1:1, as lectotype. The other syntype AMNH 27306/1:2 becomes the paratype. Figured hypotypes: USNM 152707 b,d,j-n. Measured hypotypes: USNM 152707 a-i. Unfigured hypotypes: USNM 152707 a,c,e-h.

DISCUSSION.—Our measurements and Stehli's figures indicate a transverse species but the description states that *E. minima* differs from *E. transversalis* "in being much longer in proportion to its width". Our measurements give an average length-width ratio of 0.79 which indicates a transverse shell. This figure is based on the midwidth. Using the hinge width, the ratio is 0.87, a less wide shell in proportion to its length but nevertheless transverse.

### *Elliottella multicostata*, new species

PLATE 323: FIGURES 25-58

Large for genus, transversely rectangular in outline, hinge generally wider than midwidth; cardinal extremities variable from slightly obtuse to extended and rounded ears. Sides gently rounded; anterior margin broadly rounded and usually gently emarginate. Surface multicostate, costae numerous, numbering about 26, with 2 to 6 in sulcus and 9 to 10 per 10 mm at margin; costae bounding sulcus often convergent; halteroid spines numerous: forming rows on costae and in row along posterior margin; spines at base of umbonal slope long and straight; costal spines bent anteriorly, becoming parallel to trail surface. Umbonal region crudely reticulated, with spines extending from nodes. Brachial valve with strong regular concentric undulations lateral to umbonal pit; costae subdued and only slightly elevated.

Pedicle valve strongly but unevenly convex in lateral profile, maximum convexity posterior to midvalve; anterior profile forming broad dome, indented medially by sulcus and having strongly sloping sides. Umbonal region moderately inflated; median region strongly convex; sulcus originating on posterior side of venter, narrow, variable in depth but generally moderately deep; flanks bounding sulcus moderately swollen; anterior slope long, convex, and fairly steep. Ears deflected and slightly convex.

Brachial valve geniculated near midvalve; deeply concave, greatest depth near midvalve; lateral and anterior slopes steep; median fold low, incon-

spicuous, originating just posterior to midvalve; umbonal pit moderately deep. Ears deflected, slightly concave.

Pedicle valve interior with adductor field only slightly thickened; myophragm elevated but short and low.

Brachial valve interior with small sessile, marginiferid cardinal process; lateral ridges moderately developed and forming fairly strong, striated ear baffles not extended anteriorly as ridges; adductor scars slightly thickened; brevisseptum low; endospines fairly numerous, small but stout.

MEASUREMENTS (in mm).—

	length	brach- ial valve length	sur- face length	hinge width	mid- width	height
USNM 728h						
151590a	16.0	13.5	27.0	18.2	20.7	9.8
151590b	15.2	13.3	26.0	20.5?	20.7	8.9
151590c	13.8	11.4	25.0?	18.0	19.6	8.4
151590d	13.5	11.5	24.5?	18.0	18.8	8.3
151590e	13.8	11.4	24.5	18.0	19.7	8.0
151590f	13.7	11.2	23.5	14.6?	18.0	7.8
151590g	13.6	11.0	26.0?	17.5	16.8	8.6
151590h	12.3	10.0	21.5	17.0	18.5	7.6
151590i	11.0	9.4	17.0	13.5	14.6	5.9
151590j	12.4	9.6	22.0	15.0	15.9	8.8
151590k	?	10.0	13.5	13.0	15.5	5.0
151590l	?	11.6	15.5	14.5	17.5	5.3
151590m	?	11.0	15.5	15.0	18.0	5.9
151590n	?	10.8	17.0	17.0	18.2	5.7
151590o	?	10.6	15.0	14.7	16.7	5.4
153882d (holotype)	14.5	?	25.0	18.8	18.6	8.0

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation (lower).

LOCALITIES.—USNM 728e, 728h, 746.

DIAGNOSIS.—*Elliottella* with numerous costae and spines.

TYPES.—Holotype: USNM 153882d. Figured paratypes: USNM 151589a; 153882a-c, e-k. Measured paratypes: USNM 151590a-o.

COMPARISON.—The closest species to *Elliottella multicostata* is *E. transversalis* (Stehli). The two differ markedly in the number and strength of the costae, *E. multicostata* having more numerous costae in both valves. The disparity between the costae is especially marked in the brachial valves; that of *E. multicostata* has many more costae, but they are greatly subdued and in some specimens are obscure. The sulcus of *E. multicostata* is generally less

strongly developed than that of *E. transversalis*. Spines are generally more numerous on the former species than on *E. transversalis*.

DISCUSSION.—Several fine immature specimens show well the development from an umbonally ringed stage to the adult. Most of the young appear to have been attached to productid spines, because the apex generally has a narrow and round groove. The small size of most of the attachment rings with the grooved umbo support this view. The smallest specimens are about 2 mm in diameter, with the earliest umbonal spines numbering four, one on each side and two in the middle. Others have only one in the middle. There seems to be no uniformity in the development of these structures. A specimen of 4-mm diameter has a large attachment scar and a large ring composed of two spines. A row of small spines appears along the margins of the attachment scar. Small attachment spines in addition to the ring spines may appear on the umbo. Evidently the young *Elliottella* could put out spines where they were needed.

### *Elliottella transversalis* (Stehli)

PLATE 322: FIGURES 1–43

*Marginifera?* *whitei* King (part), 1931:90, pl. 23: figs. 2a–c, 3a, b.

*Psilonotus transversalis* Stehli, 1954:324, figs. 12–16.

*Elliottella transversalis* (Stehli), 1955:711.

This abundant species in the Sierra Diablo was described fully by Stehli (1954) and needs no formal description here. The abundance of specimens in the collection, however, permits the addition of facts about the species not recorded in the original description.

The species is extremely variable, as are most productids; consequently, the costae of the exterior are not uniform, nor is the development of the fold and sulcus or the complement of spines. The costae vary from coarse, strong, and crowded to irregular, scattered, and with wide spaces between them. In some specimens the costae on the trail are very regular and fairly even in size, but in a few specimens the costae become very numerous, in others sparsely scattered. The sulcus varies from non-existent to deep and indenting the anterior margin. The specimen described by King as *Marginifera?*

*whitei* is an individual with coarse costae and no sulcus. This is not a common aberration but the U. S. National Museum of Natural History collection contains specimens like his.

The spines are variable in length and form. The trail spines of a few specimens are strongly curved coming off the costae at an angle of about 90° but bending strongly to a position parallel with the surface of the trail. In other specimens the spines extend out directly with only slight curvature when they may attain a length of 18 mm. The ear and umbonal slope spines in some specimens attain the same length.

The grooved condition of the umbo of some spat indicates that the young of this species were attached to productid spines or other round objects in their early stages. Many of these spat have the characteristic ring of one or two spines which seems to be a usual feature of the productid young. These spat also have a few ornament spines that are enormously long for such small shells.

Unlike the Glass Mountains specimens of this genus, those from the Sierra Diablo do not exhibit anteriorly elevated adductor scars inside the brachial valve. The brachial ridges of this species are not well developed.

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation (lower).

LOCALITIES.—AMNH 628, 629, 696; USNM 728e, 728f, 728h, 742.

TYPES.—Figured hypotypes: USNM 153883a–h, j–p.

### *Elliottella varicostata*, new species

PLATE 325: FIGURES 25–60; PLATE 446: FIGURES 11–17

About medium size for genus, transversely sub-rectangular outline, hinge equal to or slightly greater than midwidth. Sides gently curved; anterior broadly rounded and slightly indented medially. Ears fairly large, bluntly pointed. Surface costate and spinose. Costae strong, rounded, crowded, ranging from 4 to 6 per 5 mm on flanks, 2 to 4 in sulcus: in many specimens sulcus convergent anteriorly and pinching out earlier formed costae. Spines all of halteroid type, erect, and consisting of row along posterior margin including one on ear, curved row at base of lateral slope, and scattered

spines on visceral disc and trail, apparently without definite arrangement.

Pedicle valve fairly strongly convex in lateral profile, posterior third having greater convexity but umbonal region flattened; anterior profile strongly domed, medially indented, lateral slopes steep. Beak small, umbo flattened; posteromedian region inflated; sulcus originating on venter, narrow but nearly parallel-sided and fairly deep throughout length. Flanks rounded and steep sided.

Brachial valve conforming closely to pedicle valve, thus forming shallow visceral chamber; valve deepest medially, moderately steep sides and anterior; umbo depressed; fold low, carinate, originating slightly posterior to midvalve, indenting

margin slightly. Ears demarcated by oblique ridge, moderately concave.

Pedicle valve interior with smooth, tear-shaped adductor scars, moderately elevated; ear baffles strong, with inner surface strongly striated, and continued anteriorly as low ridge, not, however, extending around anterior margin.

Brachial valve interior with small sessile cardinal process, moderate buttress thickening anteriorly; adductor platform moderately elevated, inner pair of scars divisible into two scars, outer pair small and inconspicuous. Ear baffles low, striated on outer face and extended anteriorly along inside of lateral margin as low ridge. Brachial ridges thick and strongly elevated on anterior side of loop; brevisseptum strongly elevated and distally free.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 705a							
152706a	13.2	9.9?	25.0	18.6	16.9	8.3	?
152706b	13.2	10.2	25.0	17.8	16.5	8.3	?
152706c	13.8	11.0	25.0	17.3	17.0	8.1	?
152706d	12.6	9.6	23.0	15.8	14.6	7.9	3.4
152706e	13.3	9.8	24.0	15.8?	14.5	8.4	3.5
152706f	12.2	10.6	22.0	18.5	16.4	7.6	3.3
152706g	11.0	9.2	18.5	14.6	13.6	6.2	2.5
152706h	11.6	9.3	18.0	13.0?	13.9	5.8	2.4
152706i	11.0	9.2?	17.0	13.3	13.9	5.2	?
152706j	12.6	10.0	22.0	15.2	15.2	7.3	?
152706k	11.4	7.5	18.5	14.0?	12.3	6.5	2.6
152706l	9.9	8.0	16.0	12.0?	11.7	5.0	2.3
152706m	10.1	8.7	15.5	11.6	12.5	5.2	1.7
152706n	12.8	11.0	20.0	17.3	16.0	7.0	2.9
(holotype)							

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (lower), Cibolo Formation.

LOCALITIES.—Skinner Ranch: USNM 705a, 705n, 709v, 711p, 714e, 715v, 716p, 720e, 720g, 724p, 726h. Cibolo: 728-I, 738r.

DIAGNOSIS.—Compact, medium-sized *Elliottella* with variable costae.

TYPES.—Holotype: USNM 152706n. Figured paratypes: USNM 152706a, c, e, o, q-s; 153881a, b. Measured paratypes: USNM 152706a-m. Unfigured paratypes: USNM 152706b, d, f-n, p. Figured specimen: USNM 153910a.

COMPARISONS.—Compared to *Elliottella transversalis* (Stehli) from the Sierra Diablo, the Glass

Mountains species is smaller and less transverse and has more costae in the sulcus. *Elliottella varicostata* differs from *E. minima* (Stehli) in the variability of its costation, the deeper, subparallel-sided sulcus, and the development of a pronounced fold in the brachial valve.

DISCUSSION.—The striking feature of this species is the variation of its ornament. Although some natural variation exists in the outline and profiles as it does in all productids, these features seem relatively stable compared to the ornament. A few specimens have strong, closely crowded, rounded costae with the sulcus occupied posteriorly by 2 costae, but these median costae are pinched out

anteriorly by 2 large costae. In other specimens the sulcus is occupied by 4 or more costae from its place of origin to the front margin. The flanks of one specimen are occupied by 6 costae, but those of another have 10 or more. Bifurcation of costae is also common, and helps contribute to the variation. Another variation is that a spine base located on a broad costa may induce the formation of a superimposed rib on the costa. All degrees of change exist between the extremes of costation.

### Genus *Echinauris* Muir-Wood and Cooper, 1960

*Echinauris* Muir-Wood and Cooper, 1960:221.—Williams et al., 1965:H480.—Grant, 1968:26.—Stehli and Grant, 1970:31.

Small, subcircular to subquadrate outline; concavo-convex, with short visceral region, long trail and well-rounded area of geniculation. Ears generally small, acute. Anterior commissure with faint dorsad fold. Pedicle valve obscurely to moderately strongly sulcate. Surface provided with halteroid and ornament spines; former confined to lateral slopes, long and extending laterally or irregularly at high angle to shell surface; ornament spines short, curved anteriorly and extending at high angle. Brachial valve spines consisting of large marginal spines generally curving medially, and thinner spines scattered over concave surface at high angle. Other ornament on brachial valve consisting of shallow, scattered dimples.

Pedicle valve interior with narrow and elongate adductor platform separating flabellate diductor scars; ears with narrow, interiorly striated baffle; subperipheral rim extending from ears to anterolateral extremities. Endospines in lateral walls.

Brachial valve interior having bilobed adductor platform with interior scars tear-shaped and prominent but outer pair dendritic and obscure. Cardinal process stout, short shafted and with rounded myophore; lophidium small; brachial ridges poorly developed; ears bounded by striated, curved ridge; endospines numerous, in several rows, larger being posteriormost and decreasing in size anteriorly.

TYPE-SPECIES.—*Echinauris lateralis* Muir-Wood and Cooper, (1960:222, pl. 68: figs. 1–13).

DIAGNOSIS.—Costispiniferidae ornamented by spines and spine ridges on pedicle valve and spines and dimples on brachial valve, lateral halteroid spines long and extended laterally.

COMPARISONS.—Although *Echinauris*, when well preserved, is a very distinctive brachiopod, it is,

nevertheless, difficult to separate from several genera when the spines have been stripped away or in old specimens which have a tendency to exaggerate minor features. Compared with other members of the family, *Echinauris* is most like *Costispinifera* Muir-Wood and Cooper, *Elliottella* Stehli, and *Liosotella* Cooper.

*Costispinifera* differs from *Echinauris* in having more elaborate ornamentation and different halteroid spine arrangement. The anterior slopes of *Costispinifera* are usually strongly costate, the costae often interrupted by spine bases, but in *Echinauris* these slopes are generally without costation although in some species elongate spine bases give the appearance of costation. The visceral region of *Costispinifera* is usually strongly concentrically wrinkled in both valves but this is not true in *Echinauris*. Another distinction between these genera appears in the halteroid spines. In both genera these are mainly confined to, or most prominent on, the lateral slopes, but those of *Echinauris* are longer, thicker, and extend more directly laterally or are irregular in direction. The halteroid spines of *Costispinifera* are frequently not much larger in diameter than the ornament spines and they generally are extended strongly posterolaterally rather than laterally as in *Echinauris*.

*Elliottella* is easily distinguished from *Echinauris* because it is strongly costate, has no zone of concentrated halteroid spines, has a concentrically wrinkled visceral disc, and has no spines on the brachial valve.

Distinction between *Echinauris* and *Liosotella* in well-preserved specimens is easy. Internally, their cardinal processes differ. Moreover, *Liosotella* has prominent, spineless ears with a single row of strong halteroid spines on the lateral slopes and a strongly costate anterior slope. In worn specimens stripped of their spines, however, the distinction is not always simple.

DISCUSSION.—The exterior surfaces of *Echinauris* between the spines and their bases might be described as smooth. No prominent concentric lines are present on any of the species and no prominent radial ornament is present. Specimens vary in the development of secondary radial markings. Most juveniles and young adults do not have radial ridges, but many old specimens have interrupted ridges extending longitudinally anterior to the bases of the spines. These then suggest *Costispinifera*, but the ridges are seldom as well developed as in that

genus. The brachial valves are essentially without radial ridges of any sort and give a good clue to the generic affinities when the pedicle valve is moderately ridged.

The most conspicuous feature of well-preserved *Echinauris* is the halteroid spines. Length of the longest spine seen in the type species is 40 mm (slightly over 1.5 inches). The spines extend directly laterally in only a few specimens, most of them extending ventrolaterally or even less frequently posterolaterally. These spines spring mainly from the lateral slopes, from the ears to the anterior margin. The spines are thus bunched and form a sparse tuft overhanging the ears when viewed from the ventral side.

The ornament spines are much shorter than the halteroid spines and are usually fairly strongly curved anterodorsally. The longest spine seen is slightly less than 20 mm long in the type species. At the anterior these spines curve over the margin and over the anterior gape to some extent. A crude lateral alignment can be detected in many of the specimens. The spines appear mainly at the front margin; consequently, a row of them may appear while the shell is resting from its forward growth. When growth resumes, the margin grows away from the latest formed spines, leaving them in an irregular row near the margin.

The spine arrangement of the brachial valve appears to have less of a pattern than that of the pedicle valve. The posterior spines and those on the margins are much stouter than those covering the more median parts of the shell. These spines curve abruptly and extend toward midvalve, those from each side tangling at midvalve and forming a mat over the concave valve. The more slender spines in the median parts are given off at a high angle and may protrude beyond the shell margins. In some species they extend for a considerable distance in a dorsal direction. A specimen (USNM 152715) of *E. lappacea*, new species, from USNM 707e shows the spines on the anterior margin curving toward midvalve and tangling with those from the sides to form a mat over the concave valve surface.

A possible explanation for the spines of the brachial valve is that they fulfilled a protective role. Although many productids, such as *Elliotella*, are very similar to *Echinauris*, they are not provided with such spines. Furthermore, the possibly protective nature of these spines may be very dubious because many brachial valves in the collection are

heavily encrusted by other brachiopods and bryozoans. In some the spines serve as the substrate, but in others the intruder established itself directly on the valve surface under the mat of spines.

No ginglymus was seen along the hinge of *Echinauris*. The ventral surface on each side of the beak forms a ridge that apparently fits into a slot on the brachial valve that lies parallel to the posterior margin and just inside of it. The margins of the valve just under the beak are thickened where they fit on each side of the cardinal process to form a crude kind of articulation. The ears are variable but generally flattened in younger shells to form a small shelf, the inner slope of which is marked by oblique striae. In older shells the shelf becomes so thickened that it forms a narrow fold across the ear, and an inner thickening extends from the ear for half the distance to the anterior margin.

The adductor field is long and slender, generally not greatly thickened. The anterior pair of adductors is long and slender, lying inside the posterior pair which are less clearly defined but are also long and slender.

The anterior and lateral internal slopes of many specimens are adorned by scattered short endospines, the purpose of which is not entirely clear. In some these spines are tapered and closed at the free end, but, in others, they are open and hollow. Some appear to connect with spines on the exterior.

Although the interior of the brachial valve is similar to that of *Costispinifera*, small differences are consistent and significant. The cardinal process is short shafted and has a somewhat bulbous myophore. The ventral face is grooved, and the median lobe of the process is narrow and extends posteriorly for some distance. It is bounded by the narrower lateral lobes, leaving a narrow slit between them. The process in adults rests on a fairly thickened platform that protrudes posterior to the posterior margin. On the ventral side, the process and the lateral ridges are welded together and stiffened axially by a swollen ridge extending anteriorly to the adductor platform. The latter is present usually only in old adults. The lateral ridges are short and are not extended parallel to the posterior margin but extend anterolaterally in the same line as the ear baffles. On the dorsal side of the cardinal process the lophidium is short, narrow, and carinate, just a small ridge on the cardinal process platform.



The ears are narrowly rounded when seen from the inside and are divided from the visceral area by a narrow, oblique groove. The inside margin of the groove is steep and is striated along the groove and slightly anteriorly beyond it.

The adductor platform consists of two triangular patches on each side of the brevisseptum. The patches consist of a strongly thickened median pair of marks and less thickened, less clear patches outside of them. Each scar of the median pair is somewhat tear-shaped and more prominent than the outer pair. The inner scars appear themselves to be divisible indistinctly into two patches, an inner long and slender one, and an outer narrow and short one. In most specimens, the outer indistinct pair of scars is usually dendritic and without clear definition.

The brevisseptum, when clearly visible, extends from a point between the adductor scars to just beyond midvalve. In many specimens the longitudinal thickening of the cardinal process shaft and lateral ridges extends anterior to the posterior edge of the adductor scars and thus becomes continuous with the brevisseptum. In such cases the cardinal process shaft and brevisseptum appear to be one structure. The differences between the two are not difficult to detect on close examination. In large and old specimens the brevisseptum extends anterior to its anteriormost point of junction with the valve floor as a short projection with a sharp anterodorsad point.

A major difference between *Costispinifera* and *Echinauris* is the dense cover of endospines on the anterior slope of the latter as compared with the single row of large endospines in *Costispinifera*. The endospines of *Echinauris* appear in several generations, decreasing in size from the origin of the anterior slope anteriorly. The row of largest spines extends from the slope overhanging the ear groove, around the anterior, parallel to the line of slope, changing from visceral area to anterior slope. Two or more irregular rows of smaller spines appear on the higher parts of the anterior slope, the remainder of which is covered by a dense mat of pustules.

The brachial ridges are seldom very clearly impressed on the shell and present no unusual features. The lateral loops are situated near midvalve and just inside the fringe of endospines marking the lateral margin of the visceral area.

**GROWTH.**—The youngest pedicle valves are nearly circular in outline, strongly convex, and

somewhat keeled in the umbonal region. Such specimens were attached by one or more umbonal rings and perhaps by slight cementation at the beak. Many of the young show a deformity or cicatrix at the beak but this may be by impingement against the substrate rather than attachment. In any case the young of *E. lateralis* were attached and attachment rings appear on specimens as long as 9 mm. It appears, however, that after reaching a length of 10 mm, the individual attained most of its adult characters.

The brachial valve is moderately concave, has dimples and a few wrinkles but is devoid of spines for at least its first 5 mm of growth. Between the 5- and 10-mm stages, spines appear on all of the margins except near the beak. Inside, the median septum is not defined until about the 5-mm stage and the bilobed cardinal process is nearly at right angles to the posterior margin and is deeply grooved anteroventrally. It thus forms a compressed triangle when viewed from the exterior. The groove on the ventral side becomes filled at the base during growth, and the median lobe of the cardinal process begins to become prominent in the 5- to 10-mm stage.

Growth of spines on the young pedicle valve is interesting. While the valve is attached the body spines may equal or exceed the length of the spines on the lateral slopes. The body spines are long and curved over the anterior and anterolateral margins and may exceed the length of the body.

**STRATIGRAPHY.**—The origin of *Echinauris* is not now known; its superficial resemblance to *Avonia* suggests that it may have arisen from some related form in the Pennsylvanian. The earliest specimens here identified as *Echinauris* are those from the *Uddenites*-bearing Shale Member described as *E. subquadrata*, new species. Two other species, both from the Wolfcampian, are similar to *E. subquadrata*.

This small group of species is not entirely satisfactorily placed in *Echinauris* because of peculiarities of the spine arrangement, but this seems to be the best assignment according to present knowledge. This type appears also higher in the Permian where it is represented by "*Avonia*" *oregonensis* Cooper and by *Productus tuberculatus* Moeller, from Russia.

Another group of species in this genus is represented or typified by *E. irregularis*, new species. These are generally small shells with a tendency to

ventral sulcation, development of interrupted costae, and halteroid spines arranged in helter-skelter fashion. Others included in this group are *Avonia subhorrida newberryi* McKee, *E. parva*, new species, *E. crassa*, new species, and several undescribed species that are insufficient in number and preservation. This group of species belongs mainly to the Leonardian.

*Echinauris lateralis* Muir-Wood and Cooper, the type species of the genus, is the leading form of another stock which is characterized by the direct lateral extension of halteroid spines. This stock appears to be confined to the Road Canyon and Word formations and includes *E. lappacea*, *E. liumbona*, *E. productelloides*, and *E. magna*, all new species.

The present list of species assigned to *Echinauris* does not exhaust the possibilities. The genus is common throughout Word equivalents in parts of western United States that are still poorly known paleontologically. It is common in Permian deposits in Utah, Arizona, Wyoming, Nevada, and California. Undescribed species are present in the Guadalupe Mountains of Texas and New Mexico. It seems to be found chiefly in limestone.

In the Glass Mountains specimens of the *E. irregularis* group are commonly found in the biohermal limestones of the late Leonardian; the *E. lateralis* group, on the other hand, is generally found in dead-shell associations in sandy or dirty limestone. The Word formation has no biohermal associations. Grant (1968) presented an account of the living habits of species that lived apart from bioherms.

The holotypes of some of the following new species are too fragile or too spinose to be measured accurately without serious damage. Dimensions can be estimated fairly closely from the photographs on the plates.

### *Echinauris bella*, new species

PLATE 326: FIGURES 1-58; PLATE 410: FIGURES 9-13

Small, young adults usually equal in length and width, old adults elongate oval in outline; deeply concavo-convex; sides gently rounded; anterior margin varying from broadly to narrowly rounded. Hinge usually equal to midwidth. Ears large, nearly at right angle. Surface mostly smooth but with few wrinkles just inside ears; concentric growth lines and few growth lamellae appearing on anterior

slope. Halteroid spines long and slender, attaining length of 12.5 mm on specimen 8 mm long; halteroid spines concentrated on ears, posterior margin, and lateral slopes, usually extending laterally but also irregular. Body spines shorter than halteroid spines, usually more slender, curved, anteriorly overhanging brachial valve. Brachial valve with wrinkles on ears; moderately spaced hairlike spines covering entire surface.

Pedicle valve unevenly convex in lateral profile, umbonal region strongly and narrowly curved, remainder moderately convex; anterior profile somewhat narrowly domed, with narrowly rounded median region and long sloping sides. Umbonal region narrowly convex merging into strongly and somewhat narrowly inflated median region. Trail long, moderately convex and steep. Sulcus not developed. Umbonal slopes precipitate; lateral slopes steeply inclined to precipitate.

Brachial valve deeply concave, deepest in postero-median region; sides and anterior sloping steeply toward midvalve; ears concave and demarcated by strongly defined, oblique ridge.

Pedicle valve interior with lightly impressed muscle field; ears without baffles.

Brachial valve interior with sessile, bilobed cardinal process; bilobation strong in ventral view but in posterior view inside edges of lobes forming poorly defined median lobe; lateral ridges nonexistent or poorly developed; ear baffles forming strong oblique ridge and, in some specimens, extended as low indistinct ridge anteriorly and medially around visceral region. Brachial ridge prominent, extending obliquely anterolaterally from adductor field, looping inside row of moderately strong endospines. Adductor field consisting of two smooth, tear-shaped scars, ear indistinctly divisible into two scars. Brevisseptum dividing adductor field, short, not reaching midvalve, distally free. Trail slope long and minutely granulose.

STRATIGRAPHIC OCCURRENCE.—Cibolo Formation, Road Canyon Formation.

LOCALITIES.—Cibolo: USNM 738g, 738-l. Road Canyon: AMNH 509; USNM 702c, 703, 703a, 703c, 703d, 706f, 707e, 710u, 710z, 712t, 720d, 721o, 722g, 724a, 724b, 724j, 726d, 737q.

DIAGNOSIS.—Small *Echinauris*, with length and width nearly equal and spines fairly scattered.

TYPES.—Holotype: USNM 154773b. Figured paratypes: USNM 149621v-z, a<sup>1</sup>-i<sup>1</sup>; 153492a-c; 153493; 154772a, b; 154733a, c.

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 707e							
149621a	10.8	7.7	20.0	9.8	10.9	6.6	3.1
149621b	10.3	?	20.0	10.3	9.3	6.1	?
149621c	10.0	?	19.0	8.9	8.9	5.9	?
149621d	9.0	7.9	15.5	9.1	9.0	4.8	2.2
149621e	9.0	7.0	17.0	9.0	8.9	5.3	2.3
149621f	8.2	6.6	15.0	7.8	8.0	4.6	1.8
149621g	8.3	6.7	15.0	9.3	8.7	5.0	2.0
149621h	8.2	6.6	14.5	8.6	7.8	4.7	2.0
149621i	7.7	6.2	14.0	7.9	8.0	4.5	1.6
159621j	8.1	?	14.5	8.2	7.4	4.5	?
149621k	7.3	5.7	13.5	7.3	7.2	4.3	1.6
149621l	6.9	5.7	12.4	8.2	7.0	3.9	1.2
149621m	7.7	5.9	13.5	6.3	7.4	4.2	2.1
149621n	6.6	5.3	11.5	5.9?	7.2	3.4	1.0
149621o	6.1	5.0	9.5	6.0	6.3	3.0	1.5
149621p	6.1	5.3	9.0	?	5.9	2.8	1.4
149721q	5.7	4.7	8.5	5.1	6.0	2.9	1.3
149721r	5.0	4.4	7.0	5.3	5.2	2.5	?
149621s	4.9	4.4	6.5	?	5.0	2.1	0.7
149621t	4.4	3.6	6.0	3.0	4.2	1.8	0.6
149621u	3.4	2.8	4.0	2.3	3.0	1.0	0.4
154773b	8.5	6.5	?	8.5	9.0	?	?

(holotype) \*

\*Measurements of holotype pedicle valve incomplete and approximate because of fragility of spines.

COMPARISONS.—This is a fairly distinctive species because of its wide hinge, very delicate spines, and the random arrangement of the halteroid lateral spines. These features distinguish it from all other species of this genus. Externally, this little species suggests *Krotovia* but the spine arrangement is different. *Krotovia* does not have large lateral spines and the body spines are in quincunx and closely matted, quite unlike those of *E. bella*. In its small size this species suggests *K. barentzi* (Miloradovich) but that species is more strongly convex in lateral profile, the length and midwidth are not nearly equal, and the body spines are more crowded than those of *Echinauris*. Furthermore, the Glass Mountains species is much smaller than the Russian Arctic form.

DISCUSSION.—The cardinal process of *E. bella* is small but not in proportion to the small size of the shell. The process, when viewed from the ventral side, is distinctly bilobed; viewed from the dorsal side, it is bilobed and a median lobe is not clear. The valve is so deeply concave that the cardinal process myophore is parallel to the valve length and faces dorsad rather than posteriorly. A median

lobe is indistinctly formed by coalescence of the inner sides of the two lobes, and in old specimens the processes are trilobate. The cardinal process thus suggests that of the Leioproductidae. A callus or platform is formed between the cardinal process and the adductor field. Commonly a ridge extends anterolaterally from it to bound the outside margins of the inner, elongate adductor scars. A second pair of ridges extends anterolaterally on the outside of the smaller and rounded outer scars.

The lateral ridges extend from the outside of the posterior platform obliquely across the ears. These are strong ridges but they become lower anteriorly to swing around the lateral margins of the visceral disc and across its anterior margin. This demarcation of the visceral disc is a reminder of the margin of the Marginiferinae but it is seldom strongly developed.

The brevisseptum arises near the posterior end of the adductor field, divides that field into two parts, and just anterior to it, ascends from the floor to jut out free as a sharp projection. The distal end of the septum does not quite reach midvalve.

The adductor field consists of two parts, a me-

dian part of two smooth scars and an outer part on each side consisting of an indistinct rounded outer scar. The two inner scars have smooth surfaces, are elongate triangular in outline, and in some specimens are clearly divisible into two scars.

The brachial ridges in most specimens are well developed. These originate at the anterior inner edge of the outer adductor scar and descend antero-laterally roughly parallel to the ear baffles or lateral ridges. They are narrowly looped on the posterior side of the band of strong endospines that occurs on the anterior edge of the visceral disc.

### *Echinauris* cf. *E. boulei* (Kozłowski)

PLATE 367: FIGURES 1, 2

*Productus boulei* Kozłowski, 1914:47, text-fig. 13, pl. 3: figs. 8, 9. [Not *Avonia boulei* (Kozłowski) King, 1931:82, pl. 20: figs. 7-9, = *Echinauris interrupta*, new species.]

Large for genus, transversely to longitudinally elliptical in outline; sides rounded to nearly straight; anterior margin broadly curved. Anterior commissure in old specimens slightly and narrowly deflected in dorsad direction. Surface with moderately long (about 12 mm) spines on both valves, those of pedicle valve sparsely to moderately abundantly scattered over surface and with narrow anterior elongated elevations; spines on lateral slopes not differentiated in size from those on shell body. Brachial valve spines concentrated peripherally, and in vicinity of ears.

Pedicle valve strongly convex in lateral profile, most convex part in umbonal region. Anterior profile broadly and moderately convex and with long, steep slopes. Umbonal region swollen, not strongly extended posteriorly in young specimens but considerably extended in old specimens. Beak small and narrowly pointed. Median region of the young, faintly sulcate in young adults.

Brachial valve deeply and evenly concave, snugly fitting pedicle valve; umbonal region deeply depressed; ears strongly deflected but small.

Pedicle valve interior with broadly flabellate adductor muscle scars; adductor track not thickened. Brachial valve interior with broadly bilobed, low cardinal process and strong lateral ridges rising proximally to base of cardinal process. Adductor field broad, not thickened in specimen USNM 153483a, but having curved ridge along anterior margin. Median septum low and slender.

MEASUREMENTS (in mm).—From locality USNM 725z, specimens 153483a and b, respectively: length 22.0, 24.0; brachial valve length 15.9, 16.3; mid-width 26.0, 27.3; hinge width 15.4\*, 23.0; thickness 4.6, (?).

STRATIGRAPHIC OCCURRENCE.—Hueco Canyon Formation (just above the Powwow Conglomerate).

LOCALITY.—USNM 499b = 725z.

DIAGNOSIS.—Moderately large *Echinauris* with poorly developed spines on the lateral slopes and ears and with strong development of longitudinal costae.

TYPE.—Figured specimen: USNM 153483a.

DISCUSSION.—It seems best to refer the specimens on which the above description is based to Kozłowski's species. They agree with Kozłowski's figures in details of the interior, in size, and in profiles. These Texas specimens are somewhat more sparsely spinose and are more costate than the Andean species. The Hueco Canyon specimens are larger and less umbonate than *E. interrupta* from the Lenox Hills Formation.

### *Echinauris circularis*, new species

PLATE 335: FIGURES 1-35

Small for genus, nearly circular outline, hinge narrower than midwidth; ears small and inconspicuous; anterior commissure without dorsad fold. Beak small and inconspicuous. Halteroid spines few, located on ears and lateral slopes. Body spines distant, fairly long, slender, sent off at high angle. Spine bases not forming ridges. Brachial valve with numerous hairlike spines.

Pedicle valve strongly convex in lateral profile and highly domed in anterior profile; umbonal region broadly swollen but not extending far posterior to hinge; median region strongly and broadly inflated; trail convex, with steep slope.

Brachial valve with poorly defined ears and great depth, sides and posterior sloping medially, deepest at midvalve.

Pedicle valve interior with muscle scars poorly impressed. Brachial valve interior with small, sessile cardinal process; muscle scars slightly thickened and brevisseptum low and short.

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITY.—USNM 721u.

MEASUREMENTS (in mm).—Thickness unmeasurable.

	length	brach- ial valve length	sur- face length	hinge width	mid- width	height
USNM 721u						
152725a	8.7	7.4	15.0	7.5	8.8	5.1
152725b	8.8	7.0	15.0	8.0	9.3	5.0
(holotype)						
152725c	7.6	6.5	11.5	7.4	8.2	3.8
152725d	10.0	8.7	17.0	8.3	10.7	5.3

DIAGNOSIS.—Nearly circular *Echinauris* with narrow hinge and swollen valves.

TYPES.—Holotype: USNM 152725b. Figured paratypes: USNM 152725a, c-g.

COMPARISON.—The circular form and swollen pedicle valve distinguish this species from *E. parva*, new species. *Echinauris circularis* is most like *E. bella*, new species, but is slightly larger, has a narrower hinge generally, and more swollen pedicle valve. Many specimens of *E. bella* tend to have a somewhat carinate umbonal region, whereas that of *E. circularis* is broadly swollen.

### *Echinauris crassa*, new species

PLATE 327: FIGURES 1–36

Small for genus, subquadrate in outline, wider than long; sides slightly oblique to gently rounded; anterior margin very broadly rounded; ears prominent; hinge wider than midvalve; pedicle valve surface marked by fine growth lines and occasional short, elongated spine bases anterior to spines. All spines stout, differentiation between halteroid and ornament spines not clear, except for position; body spines attaining length of more than 10 mm; spines few in number, well scattered. Brachial valve exterior marked by few large, scattered dimples and scattered spines.

Pedicle valve in lateral profile strongly convex, maximum convexity in mid region. Beak small; umbonal region broadly swollen and prolonged prominently posterior to hinge in adults. Median region swollen; trail gently convex but sloping steeply to margin; flanks rounded and steep.

Brachial valve evenly and moderately concave with steep lateral and anterior rims. Ears flattened, prominent.

#### MEASUREMENTS (in mm).—*Echinauris crassa*, new species:

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 703a							
152708a	12.6	8.4	?	13.1	13.1	?	5.2
(holotype)							
152708c	9.3	7.0	18.0	12.8	10.0	6.1	3.6
152708e	12.0	?	24.0	14.7	13.2	7.7	?

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain and Road Canyon formations.

LOCALITIES.—Cathedral Mountain: USNM 702, 711q, 714w, 723u, 723v. Road Canyon: USNM 702c, 703a, 721y, 724d.

DIAGNOSIS.—Small *Echinauris* with few, very stout spines.

TYPES.—Holotype: USNM 152708a. Figured paratypes: USNM 152708b-f; 154774a, b; 154775a.

DISCUSSION.—This is a rare species and only a few specimens are present in the collection. It differs from *E. irregularis*, new species, which it most resembles, in lack of interrupted costae, very strong spines well scattered over the venter and few in number. It is so unlike any of the other species

described herein that further comparison is unnecessary.

### *Echinauris interrupta*, new species

PLATE 328: FIGURES 1–33

*Avonia boulei* R. E. King (not Kozłowski), 1931:82, pl. 20: figs. 7–9.

Medium size for genus, slightly wider than long, somewhat quadrate in outline; lateral margins gently rounded; anterior margin broadly rounded. Anterior commissure not folded. Surface of pedicle valve smooth except for scattered spine bases, short and somewhat rounded in posterior region but becoming elongated anteriorly to suggest interrupted



costae. Spines mostly slender, halteroid spines concentrated on lateral slopes long and slender, but ornament spines short, curved, and slender, attaining length of about 10 mm (usually nearer 5 mm). Brachial valve with scattered dimples, and slender, erect spines scattered distantly over surface.

Pedicle valve moderately convex in lateral profile, maximum curvature at about midvalve; anterior profile steeply domed, steep-sided. Umbo narrowly swollen, umbonal slopes steep, beak strongly incurved; ears obtuse, not well defined; median region inflated; trail gently convex; flanks rounded and steep. Median sulcus poorly defined or absent.

Brachial valve deeply concave, producing very thin visceral region; concavity broad and deep, deepest at about midvalve; umbonal region deeply concave under beak; ears somewhat flattened but not strongly demarcated except by change of slope in posterolateral areas; anterior and lateral rims steep.

Pedicle valve interior with moderately developed ginglymus in some specimens; ear baffles obscure. Brachial valve interior delicate for large shell; cardinal process small; adductor field small, not thickened; median ridge low and endospines nearly uniform in size, small, delicate and covering anterior slope.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 715							
152709a	20.9	?	35.0?	21.4	23.4	10.5	?
152709b	19.6	?	33.0	15.0?	21.4	11.1	?
152709f	15.0	?	23.0	14.0	17.0	7.0	?
152709h	?	16.9	?	?	21.7	?	?
152709i	?	14.0	?	?	20.3	?	?
152709k	19.8	?	33.0	15.8?	21.4	10.0	?
USNM 701d							
152710e	18.8	14.0	31.5	15.0	20.7	9.9	2.9
(holotype)*							

\*Holotype too fragile to measure; dimensions estimated from photographs, plate 328.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch and Lenox Hills formations.

LOCALITIES.—Neal Ranch: King 193; USNM 701, 701c, 701d, 715b, 721g. Lenox Hills: 707m, 707n, 713y, 715.

DIAGNOSIS.—Subrectangular *Echinauris* with wide hinge, scattered, elongate spine bases and short, slender ornament spines.

TYPES.—Holotype: USNM 152710e. Figured paratypes: USNM 152709a; 152710a, b, i-l.

COMPARISON AND DISCUSSION.—This is an uncommon species in the Glass Mountains and seldom is found silicified. It is most numerous in the goniatite bed in the midst of the 60 feet of shale in the Lenox Hills Formation on Dugout Mountain.

*Echinauris interrupta* is one of several species having a similar habit which is clearly echinaurid but not entirely typical. Generally this group contains fairly large shells; but the spines, both ornament and halteroid, are more slender than would

be expected in shells of this size. Furthermore, the halteroid spines are about the same diameter as the ornament spines. Two species of this group appear in the Glass Mountains, that under discussion and *E. subquadrata*, new species. A third possible species occurs in rocks of Wolfcampian age in the Hueco Mountains.

*Echinauris boulei* (Kozłowski), when compared with *E. interrupta*, presents a number of obviously different features. It is much more spinose and the exterior of the brachial valve is more numerously pitted than that of the Glass Mountains specimens. Furthermore, the posterior of the Peruvian specimens is more acuminate than that of the Texas material. In addition to these features, the height of *E. interrupta* is greater than that of *E. boulei*.

*Echinauris subquadrata*, new species, also suggests *E. interrupta*, but in that species the umbo is less swollen above the hinge and is even broader than that of *E. interrupta*. The venter and trail of

*E. subquadrata* are less spinose than those of *E. interrupta*.

*Echinauris interrupta* seems to be characteristic of the Lenox Hills Formation but its occurrence in the upper part of the Neal Ranch Formation suggests a relationship between this part of the Neal Ranch and the Lenox Hills Formation.

*Echinauris irregularis*, new species

PLATE 329: FIGURES 1-24; PLATE 330: FIGURES 1-43; PLATE 331: FIGURES 1-34; PLATE 332: FIGURES 25-32

*Avonia subhorrida rugatula* R. E. King (not Girty), 1931:84, pl. 20: fig. 14.

Small, subcircular to subrectangular in outline,

length and width nearly equal; hinge wide, generally about equal to midwidth but seldom wider than midvalve; sides gently rounded to nearly straight; anterior margin gently rounded, rarely broadly emarginated.

Ornament consisting of growth lines, sporadically developed elongated ridges lying anterior to spines on trail, and irregular wrinkles on pedicle valve. Brachial valve with growth lines, scattered wrinkles, and scattered, shallow dimples. Spines consisting of halteroid and ornament spines, former bunched on lateral slopes and laterally or irregularly developed; ornament spines curved, long but seldom reaching length of halteroid spines.

Pedicle valve moderately convex in lateral pro-

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702b							
154776a	10.8	8.5	?	12.0	12.0	7.5	?
(holotype)							
USNM 702							
152711a	13.5	9.7	26.0	16.4	14.0	8.4	4.7
152711b	12.9	9.3	25.0	15.5	14.9	9.0	5.2
152711c	12.2	9.9	23.0	11.9	13.4	7.6	4.6
152711d	11.9	9.2	22.5	12.1	11.5	7.4	4.4
152711e	10.6	8.5	17.5	9.6	10.3	5.3	3.3
152711f	8.3	7.1	13.0	7.3	9.9	4.1	2.0
152711g	7.9	7.0	12.0	5.8	8.5	3.8	1.7
152711h	7.4	6.6	10.0	5.5	7.7	2.3	1.3
152711i	6.1	?	8.5	5.7	5.9	2.4	?
USNM 703b							
152714a	14.9	10.6	32.0	14.2	15.6	10.1	?
152714b	16.9	10.8	34.0	13.7	17.4	10.6	?
152714c	12.4	9.2	24.0	11.7	13.0	7.8	5.1
152714d	11.2	9.7	20.0	10.3	12.2	6.9	?
152714e	10.0	7.7	19.0	8.6	10.1	6.0	3.5
152714f	6.8	6.0	7.0	5.0?	7.7	2.1	1.4
USNM 703a							
152713a	14.1	9.0	29.0	14.0?	13.5	9.0	?
152713b	11.3	7.6?	22.0	9.7	12.5	7.6	?
152713c	10.7	8.2	20.0	10.8	11.6	6.4	3.6
152713d	9.3	7.5	16.0	8.0	10.8	5.5	2.6
USNM 702c							
152712a	13.5	10.3	25.0	14.0	14.8	8.4	5.5
152712b	14.6	9.6?	30.0	15.0	13.7	10.0?	?
152712c	12.2	9.2	24.0	11.8	13.1	7.3	3.8
152712d	10.8	7.7	21.5	11.3	11.6	7.0	3.3
152712e	10.0	7.7	17.5	10.5	11.1	5.7	2.7
152712f	7.9	6.6	12.5	7.4	8.2	3.5	1.4
152712g	5.7	4.8	6.5	4.7	5.9	2.0	1.3
152712h	4.7	4.2	5.0	?	4.9	1.6	0.9
152712j	7.9	5.9	11.0	7.3	8.6	3.4	2.2

file, posterior narrowly convex; anterior profile narrowly domed, with steep sides. Beak small, umbonal region varying from slightly elongated behind posterior margin to greatly elongated; visceral hump strongly swollen; trail long, inflated and moderately convex; median sulcus variably developed, usually scarcely defined. Flanks well rounded; ears small, flattened to gently convex, varying from acute to obtuse but usually nearly right angle.

Brachial valve concave with maximum concavity at middle or slightly anterior, margins steeply elevated; umbo shallowly depressed; ears flattened but ridges setting them off not strongly developed.

Pedicle valve interior with slightly thickened adductor field and inconspicuous ear ridges. Brachial valve with adductor field strongly thickened in adults, interior scars larger, ranging in shape from teardrop-shaped to triangular; median septum prominent; cardinal process usually with bulbous myophore; lateral ridges usually only slightly developed; endospines small.

STRATIGRAPHIC OCCURRENCE.—Bone Spring, Skinner Ranch, Cathedral Mountain (Wedin Member) and Road Canyon formations.

LOCALITIES.—Bone Spring: AMNH 591, 678. Skinner Ranch: USNM 727a. Cathedral Mountain: AMNH 500, 500C, 500F, 500H, 500N, 500X; USNM 702, 702a, 702b, 702ent, 702-low, 702un, 703a<sup>1</sup>, 703b, 703bs, 708, 711q, 712o, 721u, 723k, 723p, 723u, 726o, 726u, 726y, 733m, 735b. Wedin Member: USNM 700-1, 700x, 714v, 714w, 717e, 723v, 727p. Road Canyon: AMNH 501, 503; USNM 702c, 703a, 703c, 703d, 706f, 707e, 709c, 719x, 721j, 721s, 721y, 724a, 724b, 724j, 726z.

DIAGNOSIS.—Small *Echinauris* with fairly numerous strong spines on body, lateral spines irregular, interruptedly costate on trail.

TYPES.—Holotype: USNM 154776a. Figured paratypes: USNM 154776b; 154777a-i; 154778a-c; 154779a-k; 154780a; 154781a, b; 154786a-g; 154787a-e; 154788a-c; 154789a. Measured paratypes: USNM 152711a-i; 152712a-h, j; 152713a-d; 152714a-f.

COMPARISON AND DISCUSSION.—Specimens of small *Echinauris* are fairly common in most of the levels of the "Leonard Formation" of the King brother's first report (in P. B. King, 1931) representing about 300 feet of section. This includes zones characterized by *Institella*, *Torynechus*, and *Edriosteges*. Naturally, in a span of sediments representing a

fair amount of time, considerable variation is encountered.

Deviation appears in the arrangement and size of spines rather than in dimensions, which seem remarkably uniform in generous lots from the four principal localities. The spines vary in length and diameter on the body of the shell and more prominently on the lateral slopes, where the long halteroid spines are located. These are not all directed laterally as they are in *E. lateralis* Muir-Wood and Cooper but may take off in almost any direction. Regardless of direction they seem to have served the purpose of steadying the shell on the sea bottom or anchoring it in mud.

*Echinauris irregularis* suggests a larger *E. parva*, new species, but the latter species appears to be proportionately wider, although the spine arrangement of the two is very similar. Size is an important distinction between the two species because *E. irregularis* is almost twice the size of *E. parva*.

*Echinauris crassa*, new species, suggests *E. irregularis* but is not so costate anteriorly and its spines are much thicker, stronger, and less numerous. *Echinauris lappacea*, new species, is about the same size as *E. irregularis*, but its umbonal region is not so strongly swollen as that of the Leonardian species, the spines are thicker and less numerous on the pedicle valve and are thicker on the brachial valve as well, but more densely crowded. *Echinauris liumbona*, new species, also suggests *E. irregularis*, but, like *E. lappacea*, the body spines are stronger and thicker, the umbonal region is generally nearly smooth, and the specimens are somewhat wider proportionately to *E. irregularis*.

*Avonia subhorrida newberryi* McKee (1938) includes specimens approximately the size and form of *E. irregularis*. Although no interiors of this subspecies are now known, its exterior characters place it with *Echinauris* and it is provisionally assigned to that genus. The spines are not preserved and their bases are not distinguishable on most of the type specimens. All but one of the specimens in McKee's type lot of 7 specimens are wider than long and have the umbonal region extended considerably beyond the hinge. The pedicle valve is fairly strongly sulcate, with the sulcus originating on the venter. This feature is a distinction from most specimens of *E. irregularis*. Interrupted costation is plain on most of the specimens and is somewhat coarser than that encountered in the Glass

Mountains species. The spines, from what can be seen of their bases, appear to have been well scattered and slender, somewhat more so than in *E. irregularis*.

The form, size, and ornamentation of *A. subhorrida newberryi* seem to have little in common with the type specimens of *E. subhorrida* (Meek). It is suggested, therefore, that McKee's species be known as *E. newberryi*.

*Echinauris lappacea*, new species

PLATE 336: FIGURES 1-31; PLATE 476: FIGURES 1-18

Small for genus, wider than long, subrectangular in outline; sides gently rounded; anterior margin nearly straight; hinge variable, usually not equal to midwidth; ears small, angular. Pedicle valve with scattered spines of nearly equal size, except on lateral slopes, there longer and directed somewhat posterolaterally; brachial valve with large spines around margin directed medially and forming mat

over valve; small erect spines covering remainder of valve.

Pedicle valve strongly and fairly evenly convex in lateral profile; maximum convexity in posterior third; anterior profile domed, dome flattened on top but with very steep sides. Beak small, umbonal region not greatly swollen in adults, considerably more so in old specimens. Median and posteromedian regions strongly swollen; sulcus shallow and inconspicuous, originating on trail and extending to anterior margin, there causing slight flattening. Trail long, gently convex; flanks rounded and steep.

Brachial valve moderately deeply convex, greatest convexity near midvalve; umbonal region more deeply concave and separated from flattened ears by low oblique ridges. Lateral and anterior rims steep.

Pedicle valve interior with little thickening of adductor field; ears concave but ear baffles moderately developed, striated. Brachial valve interior with small and delicate cardinal process, adductor platform moderately thickened and endospines forming one prominent row.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 707e							
152715a	13.3	11.3	22.0	15.0	15.8	8.0	4.0
152715b	13.0	10.8	19.0	14.4	14.9	7.0	?
152715c	12.2	9.3	23.0	15.0?	15.0	7.5	?
152715d	12.7	10.2	23.5	13.0	13.3	7.7	4.2
152715e	10.9	?	19.0	11.4	13.3	6.7	?
152715f	11.3	?	23.0	12.0	11.4	7.5	?
152715g	18.0	12.4	33.0	16.6	16.2	10.8	6.0
152715h	13.2	?	24.0	11.8	13.5	7.7	?
152715i	10.0	8.0	18.0	10.9	11.4	6.0	?

(Fragile holotype not measured.)

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 703, 703d, 706f, 707e, 709c, 710u, 720d, 721j, 721o, 721r, 721w, 721x, 721y, 721z, 722e, 722v, 723x, 724b, 724c, 726d, 726e, 732j, 736x.

DIAGNOSIS.—Subrectangular *Echinauris* with low umbonal region, coarse scattered ornament spines, and thick mat of spines on brachial valve.

TYPES.—Holotype: USNM 154822d. Figured paratypes: USNM 152715c, 154520a-f, 154821a, 154822a-c, 154823a-e, 154824a, 154825a.

DISCUSSION.—This suggests *E. liumbona*, new species, from approximately the same stratigraphic level. It differs in its more nearly square outline, less swollen umbo, thicker spines, and nearly complete lack of interrupted costae-like spine bases. The brachial valve is quite different from that of *E. liumbona* because it is covered by a dense mat of spines, the larger ones crowding the margins and overhanging midvalve.

*Echinauris lateralis* Muir-Wood and Cooper is much larger, with somewhat more scattered spines,

somewhat finer spines in comparison to those of *E. lappacea*, and with a less dense concentration of spines on the brachial valve of *E. lateralis*.

*Echinauris lateralis*, Muir-Wood and Cooper

PLATE 333: FIGURES 1-34; PLATE 334: FIGURES 1-33; PLATE 335: FIGURES 36-51; PLATE 468: FIGURES 5-9

*Avonia subhorrida* R. E. King (not Meek), 1931:84, pl. 20: figs. 10, 11.  
*Echinauris lateralis* Muir-Wood and Cooper, 1960:222, pl. 68: figs. 1-13.

Medium size, subpentagonal to elongate, subrectangular in outline in adults but transversely subrectangular in juveniles; ears small, not usually extending beyond midwidth. Sides moderately rounded, anterior margin nearly straight, medially to gently rounded; anterior commissure unfolded. Spines of two kinds; halteroid spines long and extending laterally to posterolaterally, attaining length of nearly 2 inches (5 cm); ornament spines more slender and shorter than halteroid spines, curved anteriorly and attaining length of nearly 1 inch (2.5 cm). Brachial valve with spines of two sizes; thick and heavy spines around the margins, curving abruptly medially; finer spines arising from valve surface at high angle, usually not extending beyond shell margin. Surface of pedicle valve with

sparse wrinkles and fine growth lines, but radial marks few and consisting of short ridges anterior to spines, best developed, if at all, in old adults. Brachial valve surface marked by occasional wrinkles and growth lines but also by scattered dimples corresponding to larger spines of opposite valve.

Pedicle valve strongly convex in lateral profile, maximum curvature in posterior third; anterior profile narrowly domed and with precipitous sides. Beak small, incurved and protruding beyond hinge; umbo narrowly swollen; posteromedian region strongly swollen; trail long and fairly strongly curved; median region depressed from place of geniculation to anterior margin by shallow, frequently barely discernible sulcus. Flanks rounded and steep.

Brachial valve deeply and evenly concave, maximum concavity near midvalve. Umbonal region shallowly depressed; ears flattened and separated from main concavity of valve by oblique ridge.

Pedicle valve interior with long adductor platform moderately elevated; ears with low baffle and deep longitudinal groove in adults. Brachial valve interior with bulbous cardinal process having longitudinally thickened shaft in adults, moderately thickened adductor field, strong brevisseptum, and anterior slope covered by endospines lessening in size and strength anteriorly.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706e							
149698a	23.4	14.4	51.0	19.8	22.0	15.3	8.0
149698b	21.6	13.5	43.0	22.4	22.0	13.7	6.0
149698c	19.8	13.0	37.0	19.0	21.0	12.0	6.6
149698d	18.8	12.8	41.0	16.2?	19.0	13.6	8.4*
149698j	15.8	13.3	35.0	18.0	18.8?	11.0?	6.5
149698k	11.8	9.9	19.0	11.4	15.4	6.0	3.3
149698l	8.5	7.6	12.0	6.0	8.9	3.4	1.8
149698m	8.3	7.1	13.0	7.4	9.0	3.8	2.3?
149698n	4.3	3.4	6.0	2.9	3.9	1.4	0.8
149698o	22.9	?	48.0	19.0	21.8	15.2	?
149698p	15.3	?	21.5	14.6	18.9	8.2	?
149698q	12.9	?	20.0	12.9	15.6	5.7	?
149698r	10.2	?	15.5	8.4	11.9	4.5	?

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation, Word Formation (China Tank, Willis Ranch, Appel Ranch members, and lenses between the last two).

LOCALITIES.—Road Canyon: USNM 713, 716xa. Word: USNM 737b, 741p. China Tank: USNM 703e, 706, 706c, 706z, 726r, 733q. Willis Ranch: AMNH 505, 506; USNM 706, 706e, 718d, 723t,



724u, 735c. Lenses: 706b, 732c, 737w, 742b. Appel Ranch: 704, 706d, 714o, 715i, 719z, 726t.

DIAGNOSIS.—Medium *Echinauris* with length and width nearly equal, faintly sulcate, with well scattered body spines, and longer nearly straight halteroid spines extending laterally.

TYPES.—Holotype: USNM 124052a. Figured paratypes: USNM 124052c-e, g, j. Unfigured paratypes: USNM 124052b, f, h, i, k. Figured hypotypes: USNM 149696a-e; 149697a-z, a'-g'; 149699; 153916. Measured hypotypes: USNM 149698a-d, j-r.

COMPARISON AND DISCUSSION.—This species is abundant in the Word Formation (Willis Ranch Member), which yields excellently preserved specimens from mere spat to old adults, but is rare in the other limestone members of the formation. The youngest specimens are about 2 mm long and are nearly circular. They are provided with a small ring of spines at the umbo and undoubtedly were attached to parental spines or other small round objects. Attachment rings may be preserved in specimens up to 10 mm in length, but they are rare in specimens that large.

*Echinauris lateralis* also suggests *E. liumbona*, new species, but the Road Canyon species is smaller and has longer and more curved body spines. *Echinauris subhorrida* (Meek) has been widely identified and specimens of *E. lateralis* have been placed under this name. The size of the two species is about the same, but the Phosphoria species has on the pedicle valve a conspicuous sulcus lacking in *E. lateralis*. Furthermore, from a study of spine bases on the type specimen, the spines of *E. subhorrida* appear to have been finer than those of *E. lateralis*, more numerous, and to have been more liberally provided with elongated bases than the Word species.

Comparisons with *E. lappacea*, and *E. producteloides*, both new species, are made under those species.

### *Echinauris liumbona*, new species

PLATE 337: FIGURES 1-36

Small to medium, subquadrate in outline; length and width approximately equal; sides rounded; anterior margin slightly emarginate. Anterior commissure with slight dorsad flexure. Ears small, forming approximately right angle. Ornament spines of pedicle valve long and stout, attaining length of

about 15 mm. Halteroid spines about same diameter but not thickly developed on lateral slopes. Brachial valve with dimples; stout spines around elevated rim and ears, less common in midvalve.

Pedicle valve with uneven lateral profile, greatest curvature on visceral hump and umbonal region. Anterior profile forming steep-sided dome flattened somewhat on top. Umbonal region strongly elevated posterior to hinge, with few spines or spine bases; posteromedian region strongly swollen; trail convex, with steep slope; sulcus originating on anterior side of visceral hump, shallow, inconspicuous but extending to anterior margin, there forming slight indentation. Flanks narrowly rounded and with precipitous sides.

Brachial valve deeply concave, most concave in median region; ears well demarcated by slope change in posterolateral regions; lateral and anterior rims steep, median fold barely perceptible.

Pedicle valve interior with adductor field not thickened; ear baffles well developed. Brachial valve interior with small cardinal process on thickened platform; lateral ridges strong; slopes to ears striated; adductor field small, moderately thickened. Endospines moderately large in one or two rows.

MEASUREMENTS (in mm).—Thickness unmeasurable.

	brach- ial valve length	sur- face length	hinge width	mid- width	height
USNM 703d					
152716a	14.8	10.2?	32.0	18.2	17.6
152716b	15.6	10.6?	32.0	15.2	16.7
152716c	14.0	9.6	31.0	14.7	14.8
152716d	12.1	8.4	26.0	13.1	14.1
152716e	10.4	8.6	21.0	11.0	13.4
152716f	7.6	6.6?	12.0	7.0	9.4
152716g	6.0	4.9?	8.0	5.8	7.0
152716h	13.0	9.7	25.0	12.2	14.6
152716o	12.4	?	c.27.0	13.0	14.0
(holotype)					8.5

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—AMNH 503; USNM 703, 703c, 703d, 721j, 721z.

DIAGNOSIS.—Subrectangular *Echinauris* with few spine ridges, emarginate anterior, and naked or nearly naked umbones.

TYPES.—Holotype: USNM 152716o. Figured paratypes: USNM 152716-l, 154826a-e, 154827a.

Unfigured paratypes: USNM 152716a-k, m, n. Measured paratypes: USNM 152716a-h.

DISCUSSION.—This species is most like *E. lateralis* Muir-Wood and Cooper but has some resemblance to larger individuals of *E. irregularis*, new species. It differs from the former in not being so umbonate, in having longer, curved ornament spines, and having the halteroid spines less strongly differentiated than they are in *E. lateralis*. It differs from *E. irregularis*, new species, in having a different size and shape, not always detectable in some crushed individuals, in having few and subdued elongate spine ridges, and much less umbonate pedicle valve.

*Echinauris productelloides*, new species, resembles *E. liumbona* but is larger, not strongly umbonate, is more swollen, and has its maximum convexity nearer midvalve. Like *E. productelloides* the spines of both kinds are of about the same diameter, but those of *E. liumbona* are longer and more curved on the body. Furthermore, the umbonal region of *E. productelloides* is moderately spinose.

*Avonia dorsoconcava* McKee from the Kaibab Limestone of the Grand Canyon region appears to belong to *Echinauris* and suggests *E. liumbona*. It differs, however, in having a fairly strong sulcus in the pedicle valve, the strongest sulcus yet seen in the genus, in having fairly strong interrupted costation on the trail, and a narrow umbonal region. The nature of its spines is unknown.

*Echinauris magna*, new species

PLATE 338: FIGURES 1-27

*Pustula subhorrida* Branson (not Meek), 1930:32, pl. 8: figs. 9-11.

Large, generally somewhat longer than wide or with width and length nearly equal; outline gener-

ally quadrate; hinge usually about equal to midwidth but varying in individuals; sides rounded; anterior margin broadly rounded; anterior commissure slightly folded dorsally. Ears small, triangular, prominent, usually acutely angular. Surface of pedicle valve with umbonal region and visceral hump fairly closely covered by spines, their bases forming rounded nodes; anterior slopes and trail marked by narrow and elongated spine bases situated anterior to spines; ornament spines erect or curved, slender on flanks but those occupying sulcus stronger, larger, and erect. Halteroid spines stouter than ornament spines, about equal in diameter to median spines, long, directed posterolaterally, commonly irregular. Spines of brachial valve, erect, numerous over valve surface; slopes of anterior rim irregularly costate.

Pedicle valve strongly convex in lateral profile, maximum convexity in posterior third. Anterior profile with nearly vertical sides and sulcate dome. Umbonal region strongly elevated and extending posterior to hinge for a fourth to a fifth of valve length. Umbonal region and visceral hump strongly swollen; trail long, strongly convex in both profiles; sulcus conspicuous, originating on umbo or visceral hump and extending to anterior margin. Flanks bounding sulcus swollen and with precipitous sides.

Brachial valve deepest in median region, with strongly elevated rims; ears demarcated by oblique ridge, narrowly concave on dorsal side. Fold low, not always clearly visible, but, when well developed, forming dorsad fold in anterior margin.

Pedicle valve interior with elongated and thickened adductor field. Ear baffles prominent and thickened, strongly striated; interior extensions of spines prominent on lateral slopes. Brachial valve interior with bulbous myophore on cardinal process

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 722c							
152717a	32.4	19.8	62.0?	27.4	30.0	21.0?	11.6
152717b	29.9	17.4	60.0	31.8	29.0	20.0	9.1
(holotype)							
152717c	24.0	17.2	52.0	?	26.6	17.3	9.8
152717d	26.2	20.0	56.0	33.8	30.4	18.3	10.4
152717e	25.4	19.3	15.2	?	28.2	17.0	8.2
152717f	26.6	18.8	56.0	30.3	27.3	17.8	?
152717g	22.4	16.1	46.0	26.4	25.0	15.1	7.7
152717h	27.5	18.0	53.0	32.4	27.5	16.8	8.4

but shaft scarcely discernible. Adductor field small, moderately thickened; brevisseptum thin, bladelike, strongly elevated, highest at anterior extremity. Endospines small, forming mat on slope anterior to brevisseptum; brachial ridges well formed.

STRATIGRAPHIC OCCURRENCE.—Phosphoria Formation (Franson Member).

LOCALITIES.—USNM 722a, 722b, 722c (= 762), 722d, 760, 762.

DIAGNOSIS.—Large *Echinauris* with numerous fine spines and numerous narrow, interrupted, elongate spine bases on the trail; sulcus strong and with row of large spines up midline of pedicle valve.

TYPES.—Holotype:USNM 152717b. Figured paratypes: USNM 152717d, i; 154828a-g; 154829a. Unfigured paratypes: USNM 152717a, c, e-h. Measured paratypes: USNM 152717a, c-h.

COMPARISON AND DISCUSSION.—This is the largest of the known species of *Echinauris* and seems to be fairly common in the Phosphoria Formation of Wyoming where it has long passed under the name of *Horridonia subhorrida* (Meek). Comparison of silicified specimens of *E. magna* with the lectotype of *E. subhorrida* shows the former to have a stronger median sulcus, stronger interrupted costation, and somewhat different spine arrangement. The spine bases of the lectotype of *E. subhorrida* are not well preserved, but this specimen seems to lack the row of large spines up the valve center as in *E. magna* (see discussion of *E. subhorrida* below).

Some of the larger forms of *E. lateralis* Muir-Wood and Cooper, such as those occurring in the lens just above the Willis Ranch Member of the Word Formation (USNM 706b), have some resemblance to *E. magna* when the interrupted costae are fairly strong. These never attain the strength of

those of *E. magna* and the species does not attain the maximum size of *E. magna*. Furthermore, the spine arrangement on the two species is different, and the sulcus of the pedicle valve is narrower and not so strong as it is in the *Phosphoria* species.

*Echinauris parva*, new species

PLATE 332: FIGURES 1-24

Small, wider than long, rectangular in outline with well rounded sides and gently rounded anterior margin. Hinge narrower than midwidth; ears small, approximating right angle. Pedicle valve surface marked by growth lines and distant oblique ornament spines attaining length on venter of 10 mm; halteroid spines located on lateral slopes and ears, usually irregular in direction, commonly curved, attaining length of 25 mm. Brachial valve with scattered dimples and erect spines, those of ears commonly directed anterolaterally to cover middle of valve.

Pedicle valve strongly convex in lateral profile, posterior slope steeper and more curved than anterior slope; anterior profile domed, with steep sides but flattened crest; beak small; umbo not strongly elevated beyond hinge; median and umbonal regions strongly inflated; lateral slopes steep. Trail flattened to faintly sulcate medially.

Brachial valve deeply concave, with steep lateral rims; umbonal region concave; ears flattened and demarcated from concave valve by abrupt slope change.

Pedicle valve interior with slightly thickened adductor field; ear baffles not pronounced. Brachial valve interior with strong lateral ridges and thickened cardinal process shaft; and adductor field small

MEASUREMENTS (in mm).—*Echinauris parva*, new species:

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 716x							
152718a	9.1	7.3	18.0	9.1	10.4	5.7	2.7
152718b	8.5	6.2	15.0	8.3	9.2	5.0	2.8
152718c	7.6	6.2?	14.0	7.2	9.1	4.8?	?
152718d	7.7	6.7?	14.0	?	8.8	4.4	2.3
152718e	6.4	5.5?	8.0	5.0	7.0	2.7	1.5
154834f	8.0	6.4	14.0	7.7	8.8	5.2	3.2
(holotype)							

but much thickened. Cardinal process myophore small; brevisseptum strong; endospines large.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—AMNH 503; USNM 703, 703c, 716x.

DIAGNOSIS.—The smallest of the known *Echinauris* with delicate spines, those of the lateral margins (halteroid spines) irregular in direction.

TYPES.—Holotype: USNM 154834f. Figured paratypes: USNM 152718e, 154834a–e.

COMPARISON AND DISCUSSION.—This small and delicate species has been seen only in the Road Canyon Formation. It is most suggestive of young forms of *E. irregularis* but it is wider than specimens of that species of the same size.

*Echinauris productelloides*, new species

PLATE 339: FIGURES 1–35

Medium size for genus, wider than long, roundly elliptical outline; sides well rounded but anterior margin nearly straight. Ears small, demarcated by slight sinuation of lateral margin, approximating right angle. Pedicle valve with scattered, curved, tapering ornament spines attaining length of at least 12 mm. Halteroid spines long and slender, about same diameter as bases of ornament spines; spine bases short and narrow. Brachial valve exterior with fine, even erect spines scattered over whole surface.

Pedicle valve fairly evenly and moderately convex in lateral profile; maximum convexity near midvalve; anterior profile broadly domed and slightly depressed medially, sides of dome having steep slopes. Beak small, umbo only slightly extended posterior to hinge; umbonal and median regions broadly swollen; anterior slope steep; median region of anterior slope flattened to faintly sulcate; flanks rounded and with steep slopes.

Brachial valve moderately concave, deepest near middle; lateral and anterior rims fairly steep; ears concave, demarcated by low ridges.

Pedicle valve interior with slightly thickened adductor field; ears flattened; ear baffles forming slender ridges. Brachial valve interior with small cardinal process, slender and curving lateral ridges, and scarcely thickened adductor field.

MEASUREMENTS (in mm).—Thickness unmeasurable.

	<i>length</i>	<i>brach- ial valve length</i>	<i>sur- face length</i>	<i>hinge width</i>	<i>mid- width</i>	<i>height</i>
USNM 732						
152719a	16.7	12.4	30.0	15.9	18.0	10.0
152719b	15.6	12.0	28.0	16.0	17.7	9.0
151719c	13.5	11.5	24.0	12.3	14.3	7.2
152719d	10.9	9.2	16.5	10.3	11.4	5.2
152719e	8.0	7.1	11.5	?	9.2	3.5
152719f	4.9	3.8	8.0	?	5.6	2.1
152719g	15.9	12.4?	31.0?	17.0	19.6	10.0
(holotype)						
152719h	14.9	11.9	30.0	15.0	17.9	10.0

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member).

LOCALITIES.—Moore locality 31. AMNH 21, 28, 496, 512, 519, 600. USNM 728, 730, 732.

DIAGNOSIS.—*Echinauris* of medium size with all spines of about equal diameter and strongly swollen venter.

TYPES.—Holotype: USNM 152719g. Figured paratypes: USNM 152719e, g–l; 154830a; 154831a, b; 154832a. Measured paratypes: USNM 152719a–f, h. Unfigured paratypes: USNM 152719a–d, f.

DISCUSSION.—This is not a common species in the Getaway Limestone Member and strongly suggests *E. lateralis* Muir-Wood and Cooper. It differs from that species in its strongly swollen venter, the maximum convexity of which occurs near midvalve. The spines are different from those of *E. lateralis* because both types of spines have about the same diameter, the halteroid spines are thus long and slender; whereas the ornament spines are short, curved, and slender. The spines are also somewhat more numerous on *E. productelloides* than on the Glass Mountain species.

*Echinauris subhorrida* (Meek)

*Productus subhorridus* Meek, 1877:75, pl. 7: fig. 3a [not 3 and 3b].—Girty, 1909:265.

This species has not been identified in the Glass Mountains but varieties and subspecies of it have been named in the Guadalupe Mountains and the name has been used in the Glass Mountains. It is therefore important to identify this species positively and to indicate its range as clearly as possible.

The types are preserved in the U. S. National Museum of Natural History (15144) and are labelled as Carboniferous from Moleen Peak, Nevada. In the lot are 16 specimens, but they come from other places besides Moleen Peak; the 2 that concern us chiefly are those figured by Meek (1877, pl. 7: figs. 3, 3a and 3b).

The specimen represented by figures 3 and 3b are of the same individual, which may be identified by its nearly complete outline, deep sulcus on the pedicle valve, and nearly complete absence of spines bases, although they are abundantly depicted in the two figures. The other specimen, illustrated by figure 3a, is incomplete anteriorly, is somewhat crushed, but does exhibit abundant spine bases. This specimen is not so strongly arched as the previous one and the two appear to us to be entirely different specifically and probably also generically. Although this species has been abundantly cited in the literature, the type selected by Girty (1909, p. 265) has generally been overlooked.

According to the USNM catalogue of types Schuchert (in Merrill, 1905) gives the location of the entire lot (USNM 15144) as Moleen Peak, Nevada, but the lectotype is labelled Mahogany Mountain, Egan Pass, Egan Mountains, Nevada, and this locality is also listed by Meek (1877). A single specimen from Moleen Peak, Elko Range, west side of Long Valley appears to have nearly the same features as the lectotype. This is true also of a specimen from the Wachoe Mountains, Nevada.

Many specimens from various parts of the Permian have been referred to this species without reference to the types. Furthermore, a number of varieties or subspecies have been created which appear not to be related. For example *Productus subhorridus rugulatus* Girty appears to be referable to *Costispinifera* rather than *Echinauris* because of its strongly rugose visceral disc. This variety was also identified by R. E. King (1931) in the Glass Mountains. His specimens are clearly a mixed lot but they seem to have affinities with *Echinauris*, some belonging to *E. lateralis* Muir-Wood and Cooper, but others of uncertain relationship because of poor preservation.

McKee (1938) proposed a subspecies *Avonia subhorrida newberryi* for specimens from the Kaibab Formation of the Grand Canyon. These definitely seem referable to *Echinauris* but the species is a

small one not very similar to *E. subhorrida*. Its affinities seem rather with *E. irregularis*, new species, from upper Leonardian rocks of the Glass Mountains than with the much younger *Phosphoria* species.

In naming his species "*subhorridus*" Meek perpetuated an unfortunate misconception, saying, "In its smooth surface, deep mesial sinus, and strong spines, this species resembles the narrowest varieties of *Productus horridus* of Sowerby." He also pointed out the size difference between the European and British species when compared to the American one, and he indicated an age difference which is now known not to be true. After Sowerby's species *P. horridus* was made the type of the genus *Horridonia* Chao, many American authors uncritically placed Meek's species and ones like it in Chao's genus. The slightest comparison of any of these American shells with specimens of *Horridonia*, which is large, nearly smooth, and has its few spines almost wholly confined to the hinge area of both valves, would convince these authors that they were not dealing with *Horridonia*. This name has thus been introduced into the American literature for a genus which appears to be rare in the United States (except Alaska). *Horridonia* is not related to *Echinauris*; it is a dictyoclostid whereas *Echinauris* has affinities with the Marginiferidae.

### *Echinauris subquadrata*, new species

PLATE 340: FIGURES 1-22

Large, subquadrate in outline; wider than long, hinge about equal to midwidth; anterior margin broadly rounded; sides more strongly rounded. Surface mostly smooth but with distantly scattered, short spine bases on pedicle valve; spines short, curved, fairly stout and reaching 10 mm in length; brachial valve marked by large, distant pits or dimples and slender, scattered, delicate spines, especially on rim slopes and ears.

Pedicle valve moderately convex in lateral profile, maximum curvature in posterior half; anterior profile broadly domed and with steeply sloping sides. Beak small, umbo broad and spreading, not strongly protruding posterior to hinge; median region broadly swollen; anterior slope moderately



MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 705h							
152720	20.4	?	35.0	24.6	25.0	11.3	?
USNM 701f							
152721	20.3	16.4	33.0	21.3	24.0	10.2	4.0
USNM 701c							
152722	19.8	14.6?	?	24.7	25.0	10.5	?
(holotype)							

long and steep: median region from visceral hump to anterior margin flattened or marked by barely perceptible broad sulcus; flanks rounded and steep. Ears prominent, approximately forming right angle.

Brachial valve deeply concave but with moderate elevated rim; most deeply concave in median region; ears somewhat flattened and gently concave.

Interiors not known.

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member), Neal Ranch Formation (bed 9 of Cooper = bed 14 of P. B. King), Lenox Hills Formation.

LOCALITIES.—*Uddenites*: USNM 701f, 701u, 703o, 705h. Gaptank: USNM 701y, 713e. Neal Ranch: USNM 701c, 701d. Lenox Hills: USNM 705, 707m.

DIAGNOSIS.—*Echinauris* of large size with short and slender ornament spines, broad umbo, and swollen venter.

TYPES.—Holotype: USNM 152722. Figured paratypes: USNM 152720; 152721a,b; 154833a. Measured paratypes: USNM 152720, 152721.

DISCUSSION.—This species may be confused with *E. interrupta*, new species, or *E. boulei* (Kozlowski). It differs from the former in having less markedly interrupted costae on the trail, a less produced and much broader umbonal region, and in being proportionally much wider. All these differences from *E. interrupta* also distinguish this species from *E. boulei*.

*Echinauris subquadrata* is uncommon in the *Uddenites*-bearing Shale Member of the Gaptank Formation and in the lower to middle parts of the Neal Ranch Formation. It serves to emphasize the essential continuity of the Gaptank and Neal Ranch formations. Two silicified specimens from "Bed 12" of P. B. King (1931), which forms the crest of the ridge on the west front of the Wolf Camp

Hills, are here identified with unsilicified specimens from the *Uddenites*-bearing Shale Member. The silicified specimens preserve the spines and give a good idea of the appearance of this species in life. These two specimens have the same broad outlines and spreading umbonal region exhibited by their earlier relatives.

*Echinauris venustula*, new species

PLATE 341: FIGURES 1-56

Small for the genus, squarish in outline, sides well rounded and anterior margin broadly rounded to slightly emarginate. Anterior commissure usually straight but some with slight dorsad fold. Hinge usually narrower than midwidth; Ears small and approximating right angle. Surface smooth but with occasional concentric wrinkles and low ridges anterior to small spine bases. Halteroid spines usually lateral, scattered on lateral slopes and ears, attaining length of 15 mm in specimen 10 mm long. Ornament spines sparsely scattered, shorter than halteroid spines, extending anteriorly at about 30°. Brachial valve with strong concentric wrinkles in posterior region and with numerous fine, scattered spines especially marginally where spines point medially; strongly dimpled in some specimens.

Pedicle valve strongly convex in lateral profile, narrowest convexity at place of geniculation; trail long and gently convex; umbonal region strongly swollen, especially in old specimens. Geniculation occurring about 5 mm anterior to beak. Anterior profile narrowly domed, with steeply sloping sides. Sulcus barely perceptible, usually confined to trail. Beak overhanging posterior margin.

Brachial valve deeply concave, greatest concavity

at midvalve, all lateral slopes steep, even those of posterior. Ears small and narrow, grooved but not deeply.

Pedicle valve interior with divergent and flabellate diductor scars. Adductor scars central, elongate, slightly thickened, and not enclosed anteriorly by diductors. Ears abruptly deflected to form shallow shelf, edge forming ear baffle.

Brachial valve with fairly large bilobed cardinal process having grooved shaft when viewed from

ventral side; dorsal view showing median lobe folded posteriorly and bounded by grooves. Lateral ridge narrow but well developed; lophidium narrowly rounded. Median adductor pair thickened, tear-shaped; lateral adductor pair small and inconspicuous; ear baffles fairly thick and strongly fluted toward exterior. Endospines forming one row of strong, fairly long spines and another row sporadically developed; brachial ridges well developed, with strong elevated rim. Anterior slope finely spinose.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 726o							
152723a	12.5	8.7	27.0	12.8	10.9	7.7	5.6
152723b	12.5	7.3	26.0	10.7	11.5	7.7	4.2
152723c	11.6	?	25.0	11.8	12.4	7.5	?
152723d	11.0	8.2	20.0	11.2	12.0	6.5	3.3
(holotype)							
152723e	10.2	7.0	19.5	7.0	10.6	6.6	4.0
152723f	9.7	7.0	17.0	8.4	10.1	6.2	3.5
152723g	7.5	6.0	12.5	6.2	8.3	3.9	2.1
152723h	6.6	5.7	10.0	5.3	7.4	3.0	1.2
152723i	4.9	4.5	5.5	3.6	5.4	1.8	0.9

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITY.—USNM 726o.

DIAGNOSIS.—Small, sparsely spinose *Echinauris* with faintly developed spine ridges.

TYPE.—Holotype: SNM 152723d. Figured paratypes: USNM 152723c, m; 154867a–k. Unfigured paratypes: USNM 152723a, b, e–l. Measured paratypes: USNM 152723a–c, e–i.

COMPARISON.—This species is most like *E. parva*, new species, from the Road Canyon Formation but differs in having more swollen pedicle valves with poorer developed sulcus and deeper brachial valves. The spines on *E. venustula* are less abundant and less crowded than those of *E. parva*.

DISCUSSION.—This species has been found only with *Hercosia delicata*, new species, at USNM 726o where it is abundant. The species is variable; in late stages of growth there is a tendency toward elongation as evidenced by specimen 152723a. Variation also appears in the density of the spines but they are seldom much crowded. Dorsal spines appear as

early as the 4-mm stage of growth. Many specimens retain the early umbonal attachment spines into adulthood.

#### *Echinauris* species unidentified

Specimens of *Echinauris* not identifiable with any of the above species were found at the following localities: AMNH 369, 417, 492, ?520, 633, 634, 635, 658; USNM 700s, 700v, 702b, 702f, 702m, 702n, 704z, 705k, 707b, 707d, 707–l, 710d, 710z, 712t, 713d, 713m, 716o, 716xa, 720d, 721j, 721r, 721s, 721t, 722e, ?722f, 722h, 722j, 722–l, 723w, 725s, 725v, 725y, 726d, 726h, 726n, 726x, 738c.

#### Genus *Oncosarina* Cooper and Grant, 1969

*Oncosarina* Cooper and Grant, 1969:9.

Small, subcircular to subquadrate in outline, hinge usually equal to or slightly less than midwidth, rarely slightly greater than midwidth; cardinal extremities varying from obtuse to slightly acute;

strongly concavo-convex, pedicle valve strongly inflated. Sulcus in pedicle valve faintly developed, if present. Surface unequally costate; posterior smooth to indistinctly reticulate; trail with strong rounded costae; ears and posterolateral areas concentrically rugose. Brachial valve likewise but without spines. Pedicle valve with spines on ears and on umbonal and lateral slopes; costae bearing long, anteriorly curved spines on crests. Brachial valve posteriorly flattened but strongly geniculated in anterior part; body cavity moderately deep.

Pedicle valve interior with swollen and elongated adductor track; ear baffles fairly well developed and striated.

Brachial valve interior with moderately large, sessile marginiferid cardinal process; adductor tracks tearshaped, thickened and excavated medially and anteriorly; brevisseptum anteriorly elevated, not extending posterior to midvalve. Ear baffles well developed, extending laterally as subperipheral rim but not extending anterior to visceral region; endospines on anterior slope, thick and moderately long.

TYPE-SPECIES.—*Oncosarina spinicostata* Cooper and Grant (1969:9, pl. 5: figs. 24, 25).

DIAGNOSIS.—Rotund and tumid marginiferids with strongly costate trail and no sulcus or only a slight median depression on the pedicle valve.

COMPARISON.—This genus is most like *Elliottella*, from which it differs in its rotund exterior, lack of or faint development of a sulcus on the pedicle valve, and a brush of spines on the lateral slopes. It also suggests *Costispinifera* in external appearance, especially in the strength of the concentric undulations on the brachial valve; but *Oncosarina* does not have spines on the brachial valve. The exterior ornament of *Oncosarina* suggests *Semicostella* of the Mississippian, but that genus has a more sharply geniculated brachial valve and a much less strong development of spines, besides having a shafted cardinal process.

DISCUSSION.—This genus suggests *Elliottella* Stehli morphologically, but the expression of the shells, with their strongly rounded profile and lack of median sulcus on the pedicle valve, is distinctive. Furthermore, the species are thus far fairly restricted to the late Wolfcampian sequence.

Only one species has been found favorably silicified; the location from which it was taken appears to be equivocal, but the anatomy is beautifully dis-

played and also the growth of the shell. These details are discussed under *O. spinicostata*.

### *Oncosarina rotunda*, new species

PLATE 318: FIGURES 1-26

Small, length and width nearly equal; sides gently rounded to nearly straight; hinge width approximately equal to valve width at middle; anterior margin broadly rounded. Ears small, nearly rectangular. Concavo-convex but with fairly deep visceral cavity. Surface costate and spinose; costae irregular, few, rounded, with interspaces narrower than costae. Visceral disc region of both valves marked by regularly arranged, narrow, concentric wrinkles, those of brachial valve interrupted by deep dimples corresponding to spines of pedicle valve. Costae cancellating wrinkles on visceral disc region of pedicle valve. Spines all halteroid in character; usually row on posterior margin terminating at extremity of ears; tuft of thick spines on lateral slopes; body spines fairly numerous, scattered and erect.

Pedicle valve strongly convex in lateral profile, most convexity in posterior half; anterior profile narrowly convex and steep-sided dome. Beak strongly incurved; umbonal region narrowly swollen, extended fairly strongly posterior to posterior margin; visceral disc and midregions strongly swollen; umbonal slopes short. Sulcus scarcely developed; when present, narrow and shallow. Flanks swollen and with precipitous sides.

Brachial valve moderately concave, maximum concavity near midvalve, sides and anterior sloping moderately steeply; anterior third moderately to strongly geniculated to form costate trail. Ears small, demarcated by slight flexure toward pedicle valve.

Pedicle valve interior with enormously thickened adductor platform widening anteriorly; no ear baffles. Anterior slope with elongated pustules. Brachial valve interior with large cardinal process, thickened adductor platform and prominent brevisseptum.

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch Member).

LOCALITIES.—USNM 707a, 711d, 714t.

DIAGNOSIS.—Subcircular rotund *Oncosarina* with strongly sculptured brachial valve.

TYPES.—Holotype: USNM 149819d. Figured

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 714t							
149819a	12.2	?	23.0	11.7?	12.9	7.0	?
149819b	11.0	7.9?	22.0	10.7	12.1	7.1	5.4
149819c	11.8	?	23.0?	14.2	12.3	7.6	?
159819d	11.0	7.8	23.0	10.6	11.1	7.8	5.4
(holotype)							
149819e	9.9	?	17.0	11.5	11.3	4.6	?
149819f	11.7	9.2	22.0	10.6?	12.0	7.7	6.0
149819g	9.4	7.9	16.0	9.8?	11.4	5.4	3.1
149819j	10.2	9.2	17.0	9.8?	10.7	5.2	3.5
149819k	?	10.0	?	11.9	13.8	?	?
149819l	11.5?	?	23.0?	12.0*	13.8	8.0?	5.2
USNM 707a							
149816	12.7	8.2	25.0	9.9	10.9	8.4	4.8

paratypes: USNM 149819a, b, g, j, p. Measured paratypes: USNM 149816, 149819a–c, e–l. Unfigured paratypes: USNM 149819c, e, f, h, i, k–o.

COMPARISON.—This species is characterized by the rotundity of its pedicle valve not only in outline but in profile. In most specimens the length and midwidth are almost equal and the hinge is usually about equal to the midwidth. Furthermore, the pedicle valves are strongly convex in lateral profile. This combination of characters generally separates this species from all others. It is also more strongly wrinkled concentrically on the brachial valve than usual in the other more transverse species.

DISCUSSION.—This is not a common species; it was taken with *Scacchinella* in the western part of the Lenox Hills. The specimens have not been found in good silicified condition, and most of them were obtained by breaking them from calcarenite.

### *Oncosarina spinicostata*, Cooper and Grant

PLATE 324: FIGURES 1–42; PLATE 419: FIGURES 44–47

*Marginifera manzanica* R. E. King (not Girty), 1931:87, pl. 21: figs. 22–24.

*Oncosarina spinicostata* Cooper and Grant, 1969:9, pl. 5: figs. 24, 25.

Small, transversely subrectangular outline, hinge equal to or slightly wider than midwidth in adults. Sides gently rounded to nearly straight; anterior margin broadly curved. Ears small, nearly rectangu-

lar. Concavo-convex and with fairly deep visceral cavity. Surface costate and spinose, costae variable in number, size, and spacing, ranging from 10 to 18. Spines all of halteroid type; one row on posterior margin and one on ear extremity; concentration of spines on lateral slopes and scattered stout spines on shell body.

Pedicle valve strongly convex in lateral profile and with posterior and anterior surfaces nearly parallel; anterior profile strongly domed and with steep lateral margins. Umbonal region flattened in profile, somewhat narrowly inflated as seen from posterior and with short, steep slopes; median region inflated. Sulcus, when present, broad and shallow, originating on venter and occupied by two to four costae. Flanks well rounded.

Brachial valve deepest medially, visceral disc strongly wrinkled, wrinkles interrupted by large dimples. Sides and anterior, steep. Trail usually short, strongly costate. Ears flattened.

Pedicle valve interior with moderately developed adductor platform and poorly developed ear baffles.

Brachial valve interior with variably developed cardinal process, small and bilobed in juveniles but stout and trilobed in adults. Adductor platform consisting of two plates tilted toward side and separated by brevisseptum; lateral ridges varying from absent to moderately strong; ear baffles strong and continued anteriorly and medially to form indistinct submarginal ridge. Brachial ridges indistinct. Endospines few, but stout and long.

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch For-

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 707-1							
149823a	11.6	9.9	22.0	11.0?	14.0	6.6	3.6
149823b	11.3	8.6	22.0	13.6	13.8	7.0	3.5
149823c	10.3	8.7	17.5	13.5	13.3	5.7	3.5
149823d	10.3	8.1	18.5	11.2	11.8	6.0	4.3
149823e	9.4	7.4	15.5	11.4	10.7	4.8	2.5
149823f	8.1	6.3	12.0	?	9.2	3.8	1.5
149823g	7.1	5.7	10.0	6.8?	8.2	3.5	1.3
149823h	6.2	5.7	8.0	6.1?	7.2	2.7	0.7
149823i	6.6	6.0	9.5	6.6	7.2	3.0	1.7
149823j	11.7	9.2	23.0	12.2	12.9	8.0	4.5
149823k	10.6	8.0	20.0	9.8	11.3	6.9	4.4
149823l	10.9	7.8	18.0	11.4*	10.7	6.0	3.0
149823m	11.8	10.2	21.4	12.4*	13.0	6.5	4.2
USNM 707ha							
149825a	12.0	9.4	24.0	12.3	14.6	8.0	4.9
149825b	10.4	7.7	19.0	11.0	12.5	6.4	?
149825c	9.8	7.8	16.0	10.2	12.4	5.3	?
149825d	8.2	6.7	13.0	8.9	10.9	4.5	?
149825e	7.9	6.2	14.0	8.0	10.2	4.7	2.9
149825f	7.8	6.2	11.0	7.3	7.7	3.9	2.1
149825g	5.2	4.1	7.0	4.0	5.2	2.2	1.3
149825h	13.0	8.6	27.4	15.2	13.0	8.3	4.4
USNM 708e							
149827a	12.2	?	25.0	13.5	13.0	7.1	?
149827b	11.5	?	20.0	13.8	13.8	6.1	?
149827c	9.7	?	16.0?	13.4	11.2	5.5	?
149827d	11.5	?	21.5	13.9	12.8	6.8	?
149827e	9.4	?	17.0	12.2	12.3	5.2	?
149827f	10.0	?	18.0	10.3	11.4	5.5	?
149827g	10.6	?	19.0	13.5?	13.0	5.4	?
149827h	12.4	?	25.0	12.1	12.3	7.3?	?
149827i	9.6	?	16.5	11.0	10.8	6.2	?
149827j	7.5	?	12.0?	8.8	8.7	3.9	?
149827p	11.2	?	20.0	14.5	14.2	5.7	?
149827t	11.1	?	20.0	14.2	14.1	6.5	?
149827u	10.0	?	17.0	12.4	12.1	6.0	?
149827v	9.3	7.5	16.0	11.2	10.7	5.5	2.9
149827w	11.4	9.0	21.0	13.3?	14.1	6.9	3.9

mation (Decie Ranch, Poplar Tank, and Sullivan Peak members), Hess Formation.

LOCALITIES.—Decie Ranch: USNM 707g = 707-1. Poplar Tank: USNM 707ha, 708e, 713r, 741k. Sullivan Peak: USNM 705o, 707, 714y, 729o. Skinner Ranch (base): USNM 712p. Skinner Ranch (top): USNM 710r, 715f, 723h, 723-1. Hess: USNM 709g.

DIAGNOSIS.—Small *Oncosarina* with variable costae on trail, strongly dimpled brachial valve, and variably rugose brachial valve.

TYPES.—Holotype: USNM 149824=153884. Fig-

ured hypotypes: USNM 149823b; 149825a; 149827p; 153884a-f; 153885a, b. Measured hypotypes: USNM 149823a-m, 149825a-h; 149827a-j, p, t-w.

COMPARISON.—Although this species suggests *Elliottella* Stehli, it differs in details of the ornamentation, in the abundance of halteroid spines on the lateral slopes, and in the different development of the cardinal process. It is intermediate in size between *O. rotunda*, new species, and *O. whitei* (R. E. King). Its costation is more variable than that of the former and the costae are stronger and more elevated. The brachial valve is not so strongly and



regularly rugose as that of *O. rotunda*. This species is smaller than *O. whitei* with less uniform costation and less strongly developed concentric wrinkling on both valves.

DISCUSSION.—This species has considerable interest because of the unusual attachments developed in the young stages and the development of the cardinal process as shown by specimens from USNM 707ha. The spat were attached by a series of rings in the young stages to productid spines or other small objects. Specimens still attached to spines are present in the collection; furthermore, some of the spat attached to the rings of their brothers, the two becoming intimately entwined and usually misshapen.

The pedicle valve umbo of the spat is usually distorted and thickened. In some it is flattened where the spines were unable to clasp a round object and worked their way along the surface of the substrate. These examples are less common than those in which the umbo is distinctly grooved and was anchored by a number of spines. The smallest specimens show that the first rings appeared at the umbo and that others were added forward as needed to fix the specimen more firmly. On specimens where many of the earliest formed rings are broken away, a scar that distorts the umbo remains and the later-formed rings appear on the anterior slope. In such specimens, in which the umbonal region is generally considerably thickened, a trace of the attachment host is left as a well-defined groove. In some examples the beak region is thickened and distorted, and the remnants of the rings appear as two prongs extended laterally from the beak. Many adults retain the grooves or callosities developed in youth during the attached stages.

Some specimens of this species retained their attachment rings for a considerable period, at least until 5 mm of length had been attained. This species is variable in shape, some of the variation being attributed to crowding in early life.

The cardinal process of *O. spinicostata* in its younger phases is strongly bilobed and reminiscent of the cardinal process of the Productellinae. In young specimens this structure is bilobed with each lobe deeply grooved. With advancing age, however, the gap between the lobes is somewhat bridged by the development of a median lobe. This extra lobe is deeply indented when viewed from the ventral side; seen from the posterior, the process is

definitely trilobed and distinctly marginiferid in its type, because the indented median lobe is inclined posterodorsally.

### *Oncosarina whitei* (R. E. King)

PLATE 244: FIGURES 32–37; PLATE 310: FIGURES 42–61

*Marginifera? whitei* R. E. King (part), 1931:90, pl. 23: figs. 1a–c.

Medium size, wider than long and subrectangular in outline; hinge forming widest part of adults. Sides gently rounded to nearly straight; anterior margin broadly rounded. Ears large and flattened in adults, nearly rectangular in juveniles. Surface irregularly costate; costae narrowly rounded to broad, numbering 12 to 16, interspaces varying from narrower to as broad as costae. Spines all halteroid, numerous, stout on sides, slender on body; forming thick tuft on sides, few on posterior margin; numerous scattered spines on body.

Pedicle valve variable in lateral profile, adult usually fairly strongly convex, maximum convexity at venter, umbonal region flattened, trail slope long and gently convex. Anterior profile broadly domed, with moderately steep sides. Umbonal region broadly but moderately convex; median region inflated. Sulcus variable, usually poorly defined, originating on venter, broad and flat, occupied by one to three costae. Flanks rounded but not well demarcated from venter and trail.

Brachial valve strongly wrinkled in visceral disc and near ear, deeply dimpled over most of surface; fairly deep and with steep sides and anterior; ears flattened and defined by low, oblique ridge.

Pedicle valve interior with strongly thickened adductor platform but ear baffles not strongly developed.

Brachial valve interior with moderately large cardinal process and strongly elevated adductor platform. Lateral ridges and ear baffles moderately developed. Brevisseptum short.

STRATIGRAPHIC OCCURRENCE.—Hess Formation (Taylor Ranch Member).

LOCALITIES.—USNM 702d, 702e, 702f, 702m, 713x, 716n, 716o, 722p.

DIAGNOSIS.—Large for the genus; strong costae on the trail and numerous concentric wrinkles in the umbonal and visceral regions of both valves.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
King 107							
YPM 11685 (holotype)	14.0	10.7	27.0	15.0?	15.9	9.5	6.0
USNM 702m							
149840	15.8	11.5	28.0	?	16.1	9.1	5.4
USNM 702f							
149838	12.4	10.5	22.0	17.0	14.8	7.6	3.4
USNM 716n							
149843	13.8	?	25.0	17.0?	15.2	8.1	?
USNM 716o							
149845a	16.8	?	28.0?	20.7*	17.4	10.6	?
149845b	12.3	?	20.5	?	15.2	7.1	?
149845c	11.5	?	18.5	13.6*	13.7	5.9	?
149845d	13.2	?	25.0	17.0*	17.1	6.7	?
149845e	11.2	?	19.0	15.0*	13.7	5.4	?
149845f	12.2	?	21.0	?	13.6	6.8	?
149845g	12.0	?	21.0	15.6*	13.8	5.5	?

Types.—Holotype: YPM 11685. Figured hypotypes: USNM 149838; 149840; 149843; 149845 c, d; 153195. Measured hypotypes: USNM 149838, 149840, 149843, 149845a–g.

COMPARISON.—This species is most like *O. rotunda*, new species, in outline and profile but it is much larger and has much stronger costae on the trail.

DISCUSSION.—*Oncosarina whitei* is fairly common in the Taylor Ranch Member, but it is hard to obtain good specimens, and interiors are extremely difficult to find or to prepare. The type lot consists of three specimens, one from the Glass Mountains (R. E. King locality 107) and two from the Sierra Diablo (R. E. King locality 479). The Glass Mountain specimen is the holotype. The other two are excluded from the species, but others subsequently were found. The lithology in which they occur is extremely hard, contains scattered chert, and is a siliceous limestone. When subjected to hydrochloric acid, decalcification leaves a solid residue of silicious material retaining the form of the original piece. All of this must be picked or scraped off the specimens, a process usually destructive of spines.

The few brachial valve interiors obtained do not have anteriorly excavated adductor platforms, but they are greatly thickened and elongated as usual in the genus. The lateral ridge is fairly well developed and has strong fluting on its outer side.

Subfamily RETARIINAE  
Muir-Wood and Cooper, 1960

Marginiferidae having exterior geniculated in dorsal direction and visceral region reticulated; trail long, often tubuliform; brachial valve interior with ridges across ears, occasionally with lateral flange; anterior row of endospines present.

Genera in West Texas: *Kutorginella* E.A. Ivanova, 1951(= *Retaria* Muir-Wood and Cooper, 1960); and *Thamnosia* Cooper and Grant, 1969.

This subfamily ranges into the Capitan Formation of the Guadalupian, where it is represented by a large and highly specialized species. The two genera represented are closely related, differing chiefly in the spinosity of the pedicle valve. The subfamily Retariinae is retained even though it proved necessary to submerge the genus *Retaria* which inspired it in the synonymy of *Kutorginella*.

Genus *Kutorginella* E. A. Ivanova, 1951

*Kutorginella* Ivanov, 1935:87 [nomen nudum].—Ivanova, 1951:329.—Sarycheva, ed., 1960:234.  
*Retaria* Muir-Wood and Cooper, 1960:231.—Williams et al., 1965:H482.  
*Neoprobosciddella* Ivanova, 1949:47 [nomen nudum].

Deeply concavo-convex with brachial valve sharply geniculated; usually transversely rectangular in outline, hinge equal to or greater than mid-

width; pedicle valve sulcate; brachial valve with low fold. Pedicle valve trail nasute in old specimens. Surface costellate, with fine concentric undulations cancellating visceral disc of both valves, that of the brachial valve more strongly than other. Both valves spinose, spines consisting of ornament and halteroid spines. Ornament spines mostly in umbonal and visceral disc regions, usually slender, moderately long and gently curved; halteroid spines on posterior margin, ears, in row at base of lateral slopes above ears, a few on anterior part of trail; halteroid spines usually long and stout, some attaining length of 40 mm, especially at base of lateral slopes and on anterior part of trail. Brachial valve with scattered, long, slender spines.

Pedicle valve interior with elongate and slightly elevated adductor field and subflabellate diductor scars; posterior adductors dendritic. Ear baffles varying from obsolete to strong.

Brachial valve interior usually with moderately long-shafted cardinal process, usually narrowly trilobed, median lobe curved dorsally; cardinal process buttressed by thick ridge uniting with brevisseptum; lateral ridges strong, uniting with strong ear baffles to form marginal ridge or flange extending around visceral disc, strongly elevated in some species, less so in others. Adductor field large, sub-oval to subtriangular, posterior adductor scars large and dendritic, anterior scars small and smooth. Brachial ridges usually delicate; endospines usually small, fringing anterior end of flange or marginal ridge. Brevisseptum slender, uniting with cardinal process buttress ridge, rising to crest distally and extending to edge of visceral disc.

**TYPES-SPECIES.**—*Kutorginella mosquensis* E. A. Ivanova (1951:329).

**DIAGNOSIS.**—Transversely subrectangular Productacea having a semireticulate visceral disc region, a few long halteroid spines, and an elevated flange on the sides of the visceral disc.

**COMPARISON.**—The ornament and general exterior characters suggest the genera *Alexenia* and *Tubaria*, which occur in the Upper Paleozoic of Russia. Although the exterior of *Alexenia* is almost identical to that of *Kutorginella* and the name has been used for *Retaria*=*Kutorginella* (Stehli, 1954, and Cooper, 1957a), the interior of the brachial valve is so unlike that of *Kutorginella* as to preclude any association. In *Alexenia* the cardinal process is buttressed by two long, thin, parallel

plates that extend to midvalve. These are unique among the Productacea and clearly exclude this genus from relationship with *Kutorginella*. Probably they should not be left in the same family.

*Tubaria* is another Russian genus in which the two valves strongly resemble *Kutorginella* but the anterior is drawn into a long tube that is far more strongly developed than the nasute 'extension' of *Kutorginella*. The interior details of *Tubaria* are not now known and its family placement was based on exterior characters. It might be related to *Thamnosia* which has a strongly nasute anterior. At any rate *Kutorginella* cannot be placed in that genus.

Separation of *Kutorginella* and *Retaria* is no longer possible. The former genus cannot be said to be well known, its present description is quite sketchy and the few published figures do not permit objective independent analysis of its characters, because no spines are shown. One of the illustrated specimens is anteriorly nasute and strongly resembles some specimens of *K. sullivanensis* (R. E. King). The interior details of the brachial valve described for *Kutorginella* are identical to those of many of our specimens. The description of *Kutorginella* by Sarycheva and Sokolskaja (1952:153) is not in complete accordance with that of Ivanova (1951:329). In the former description it is stated that the spines are small, and that one row occurs along the hinge line and another on the boundary of the ears, whereas Ivanova says that there is a row of spines on the slopes toward the ears. In view of these close similarities it seems only proper that the name *Retaria* be abandoned. Muir-Wood and Cooper (1960) did not have available the extensive material on which the above remarks are based, and they felt that considerable uncertainty existed as to the true characters of *Kutorginella*. At the time they wrote they had few strongly nasute specimens of "*Retaria*." Conservatism was then appropriate, but now we are unable to separate these two genera.

**DISCUSSION.**—This is a distinctive genus, common in the Pennsylvanian and through the Leonardian stage of the Permian. Its exterior shape, profile, and ornament combine to make it easily recognizable. It is usually transversely rectangular in outline, but one species, *K. meridionalis* (McKee), is squarer in outline than most. Usually it is provided with large ears that are widely extended but generally narrowly rounded rather than alate. The lat-

eral profile of the pedicle valve is usually strongly rounded but that of the brachial valve is sharply geniculated.

The ornament of this genus is as distinctive as its shape. The visceral disc region of the pedicle valve appears to have somewhat finer and less crowded costellae than the trail area but the costellae are less cancellated in this region than those of the brachial valve. On the flatter or visceral disc region of the brachial valve, narrow undulations are fairly closely crowded and give a finely reticulate pattern to the surface. This ornament is very characteristic and one of the helpful features in identification. The reticulate pattern does not extend to the trail. In some species this pattern is complicated by superposition of dimples corresponding to the spines of the pedicle valve.

Most of the species are strongly sulcate, some less so than others, but a sulcus is invariably present. It originates near the umbo or on the visceral disc and usually extends to the anterior margin. The trail is costellate, with the costellae usually crowded and separated by spaces narrower than their width. Specimens with exceptionally long trails tend to still finer costellae or to their obsolescence. A feature common in old specimens is the narrowing and elongation of the trail to form a nose or partial trough, the brachial valve likewise becoming nasute. This feature occurs in most of the species found in the Glass Mountains.

The spine arrangement is variable among the species. *Kutorginella umbonata* (Muir-Wood and Cooper) has a single row of long slender spines over the ears on the lateral slopes, whereas *K. sullivanensis* (R. E. King) is usually provided with a single long spine in this region. The ornament spines are usually slender, tapering, and curve anteriorly. They are best developed in the visceral disc region of the pedicle valve, but a few appear on the trail.

The halteroid spines are the most conspicuous on all of the species. Those on the posterior margin generally are small and the ears are commonly naked. The lateral slopes are a major site for halteroid spines. In species such as *K. uddeni*, new species, a curved row starts on each side of the umbo and extends to near the posterolateral extremity, increasing in size in this direction and the last one usually being one of the major spines in size. The anterior part of the trail is another site for the

development of major halteroid spines. In *K. umbonata* (Muir-Wood and Cooper) long halteroid spines appear in a bunch at the anterior end of the trail, but in *K. sullivanensis*, two large spines only appear at this place, one on each side of the sulcus. The spines on posterolateral extremities and on the anterior part of the trail appear to be the major steadying spines. Most of the trail between the large anterior spines and the visceral disc edge is generally devoid of spines or marked by a few ornament spines only. The shell may have rested chiefly on this part of the trail and have been steadied by the lateral and anterior halteroid spines. This spineless portion of the trail appears in the Glass Mountains species. The full spine arrangement of Pennsylvanian members of the genus is not known, except that generally a row of spines overhangs the ears.

The brachial spines of all the species are similar. They are commonly long, slender, and hairlike, and appear to have a uniform diameter. Some concentration of these on the ears can be noted but on the remainder of the valve they are well scattered.

The flange and cardinal process are distinctive features of the brachial valve interior. The cardinal process, as in all productid genera, is variable, being long or short shafted depending on the species. The myophore is generally indented on the ventral face and is trilobed on the posterior face. It is typically marginiferid in having the median lobe deeply grooved and bent in a posterodorsal direction. The lateral lobes are generally narrowly compressed rather than widely extended. The cardinal process shaft appears to be extended anteriorly by the development at its anterior end of a buttress ridge, which extends to the proximal end of the brevisseptum to which it is united. In young specimens the ridge and septum are distinct and separate plates.

Lateral ridges of varying strength, usually strong, extend obliquely laterally from the ears. Ear baffles, a thin plate or flange, nearly upright or extended directly laterally, hang over the lateral trail area. The flange is narrow to fairly wide, extending anteriorly to the anterolateral extremity where, in some species, it diminishes in width or disappears. The flange in other species is extended as a shelf over the anterior trail area to midvalve. Along its anterior margin the flange is serrated or spinose.

The muscle area is usually variable in size and

shape, but always consists of a large dendritic portion and a smaller, anterior, nondendritic area. In *K. sullivanensis* the adductor field is fairly large and consists of two triangular patches, one on each side of the brevisseptum. Most of the posterior of these patches is occupied by dendritic muscle scars, but the anterior angle of the triangle is formed by an elongate teardrop-shaped, nondendritic scar.

***Kutorginella dartoni* (R. E. King)**

*Productus dartoni* R. E. King, 1931:67, pl. 10: figs. 12, 13.

Small, subrectangular outline, longer than wide; hinge straight and wide, but widest part near midwidth; sides gently rounded; anterior margin broadly rounded; surface costellate, costellae numbering about 5 per 5 millimeters at front margin; spines scattered on body and trail. Spine pattern not preserved.

Ventral valve strongly but unevenly convex in lateral profile, greatest convexity about half-way anterior to beak, but posterior third somewhat flattened; anterior profile broadly rounded with long steep sides and median region depressed by narrow sulcus; umbonal region narrowly rounded and not greatly elongated in dorsal view; median region swollen; trail convex and long; sulcus originating at umbo, narrow and shallow to anterior margin. Flanks rounded, sides steep; cardinal extremities flattened and deflected into small ears; visceral region of dorsal valve finely reticulate.

Dorsal valve gently concave in visceral region, strongly geniculated farther anterior; umbo and median region forming most concave part; flanks flattened; anteromedian part of visceral disc marked by low but indistinct fold. Ear baffles well developed, anterior of visceral region inside the dorsal valve marked by low spiny ridge on margin.

MEASUREMENTS (in mm).—From King locality 460, lectotype YPM 10739: length 20.0?, dorsal length 14.6, midwidth 24.5, hinge width 19.8?\*, thickness 11.4, surface length 41+.

STRATIGRAPHIC OCCURRENCE.—Hueco Canyon Formation.

LOCALITY.—R. E. King locality 460, South of Victorio Peak above Millican.

TYPES.—Lectotype: YPM 10739.

SELECTION OF TYPE.—This species is based on

two cotypes, YPM 10739, from the Hueco Canyon Formation, south of Victorio Peak above Millican (King locality 460), to which was attached a specimen of *Composita* called *C. mira*, and YPM 10740, a pedicle valve from the "Lower Gym" Formation on the slopes of Juan Peak (King locality 385).

The specimen of *Composita* was removed from inside the outer concave surface of the dorsal valve. The dorsal valve is thus revealed in most of its detail in YPM 10739. The specimen is so broken along the anterior and on the margins near the cardinal extremities that the ear baffles and the margin are exposed. This specimen (YPM 10739) is more revealing than that from Juan Peak, which does not show the dorsal valve or any details of the interior, and therefore is selected as type of the species.

The type selected seems to be different from the "Gym" form which has a lower umbo but a more swollen ventral valve, a deeper sulcus, and a much more strongly reticulate ventral visceral region.

***Kutorginella robusta*, new species**

PLATE 350: FIGURES 5–20

Large for genus, transversely rectangular in outline; hinge wide; ears large and extended laterally beyond midwidth; sides rounded; anterior margin broadly rounded, occasionally producing nasute extension. Anterior commissure with slight dorsad fold. Beak small, incurved. Surface marked by flatly convex, crowded costellae, about 8 per 10 mm at front of adults. Visceral disc regions of both valves strongly and finely reticulated. Spines on pedicle valve numerous, mostly slender and delicate but with a few large. Spines forming single row of 7 or 8 on lateral slope over ears in large adults, these spines becoming increasingly large anterolaterally; largest and longest one usually last row; body spines and those of visceral disc short and delicate; spines on anterior part of trail not numerous, usually delicate but with occasional ones of about same diameter as last in lateral row. Ears usually without spines; posterior margin generally without spines. Brachial valve with numerous long, hairlike spines, concentrated or best preserved on lateral and anterior slopes. Brachial valve strongly reticulated.

Pedicle valve strongly and fairly evenly convex in lateral profile, and broadly domed in anterior



profile, top notched by median sulcus. Umbonal region swollen but not protruding strongly posterior to hinge; median region very strongly swollen; sulcus originating on umbonal region, usually broad and shallow, becoming shallower near anterior margin and in few specimens disappearing to form flattened indistinct costellate area. Ears wide and narrowly rounded. Anterior slope steep. Trail long, with tendency to lobation in some specimens.

Brachial valve with broad, shallow depression forming umbo; nearly flat or slightly concave for about two-thirds of length, there strongly geniculated at about right angle or slightly less. Ears flattened and defined by oblique ridge.

Pedicle valve interior with elongated and thickened adductor platform in old shells, posterior part

dendritic; diductor scars large and flabellate but not enclosing adductors. Ear baffle thin, oblique.

Brachial valve with variable cardinal process, thin and delicate with depression on ventral face and bilobed myophore; developing to stout, knob-like process strongly bilobed and greatly thickened. Buttress ridge usually thin but variable, some being thick but all uniting with brevisseptum; adductor scars forming two strongly dendritic triangular patches; brevisseptum, when well preserved, low, bladelike and extended anteriorly as free point over anterior slope; brachial ridges laterally extended, usually not strongly thickened. Lateral ridges joining lateral flanges, these widest anterolaterally but extended medially only as two rows of short, stout spines.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 721o							
149887a	27.3	21.2	64.0	43.3?	42.8	21.0	12.4
149887b	25.7	22.6	57.5	39.4	38.0	19.7	10.6
149887c	27.8	22.4	?	46.0*	27.8	18.5	12.2
(holotype)							
149887d	25.2	21.9	54.0	48.0*?	39.3	17.3	9.0

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 719x, 721o, 721s.

DIAGNOSIS.—Large *Kutorginella* generally with delicate spines and a spine row over the naked ears.

TYPES.—Holotype: USNM 149887c. Figured paratypes: USNM 149886a, 149887d, 154025a. Measured paratypes: USNM 149887a, b, d. Unfigured paratypes: USNM 149887a, b.

COMPARISON.—This species is most like *Thamnosia anterospinosa* Cooper and Grant and *Kutorginella umbonata* (Muir-Wood and Cooper). The great mass of halteroid spines on the anterior of the trail characteristic of *T. anterospinosa* is a ready means of separating it from *K. robusta*. Separation from *K. umbonata* is fairly easy because that species is generally somewhat shorter and has a greater tendency to anterior lobation which is seldom seen in *K. robusta*. The lateral row of spines is usually 7 or 8 in *K. robusta* rather than five, and the trail spines are usually less strongly developed than those of *K. umbonata*. The cardinal process

of *K. umbonata* is not so strongly developed as that of *K. robusta*.

DISCUSSION.—This species is obviously related to *K. umbonata* (Muir-Wood and Cooper) because it has a similar lateral row of spines and a tendency to anterior lobation. The latter never seems to materialize in most of the specimens. A considerable difference can be noted in the development of the cardinal process of the two species. Both are narrow and slender in the young but that of *K. umbonata* remains long and slender throughout life in the majority of specimens. It also retains the median distal depression on the ventral face. In the development of the cardinal process of *K. robusta* the process swells distally and the myophore becomes bulbous when viewed from the ventral side and strongly trilobed, from the posterior or dorsal sides. Size does not always determine the degree of growth of the cardinal process. One fully grown brachial valve, fairly thickened and truly adult in every respect, has the cardinal process small and delicate, entirely like that of a juvenile.

*Kutorginella sullivanensis* (R. E. King)

PLATE 237: FIGURES 9-12; PLATE 342: FIGURES 1-34; PLATE 350: FIGURES 1-4

*Productus dartoni sullivanensis* R. E. King, 1931:67, pl. 10: fig. 14.

About medium size for genus; transversely rectangular in outline; hinge forming widest part; ears large and narrowly rounded, convex on pedicle side. Anterior margin strongly nasute; sides sloping medially. Surface of both valves costellate and spinose. Lateral slopes of visceral disc region marked by few strong concentric rugae cancellating the costellae; visceral disc with narrowly rounded costellae; trail costellae broad and flattened, separated by fine striae, numbering 4 to 6 per 5 mm on trail; nasute part of trail with costellae subdued to obsolete. Brachial valve with finely cancellated ornament. Spines few on pedicle valve; a few small spines on posterior margin; large stout spine attaining length of 35 mm on lateral slope, slightly anterior to and above ear; two large, stout spines attaining length of about 35 mm on trail, just posterior to nasute extension; small widely scattered spines, few in number, on shell body. Brachial valve with scattered, long, hairlike spines.

Pedicle valve unevenly convex in lateral profile, valve humped strongly anterior to midvalve, visceral region shorter than trail and moderately convex, trail long and gently convex. Anterior profile steep

sided, domed, deeply indented on top. Umbonal and visceral regions moderately swollen, steep slopes to lateral extremities. Median region strongly convex. Sulcus originating near middle of visceral disc, narrow and deep, dividing shell into two lobes. Flanks bounding sulcus strongly swollen. Sulcus extending onto nasute portion but becoming obsolete or nearly so. Nasute extension pointed in some specimens but generally narrowly truncated.

Pedicle valve interior with moderately thickened and elongated adductor field. Ears without baffles but with spines along inner margin facing visceral region.

Brachial valve with small, erect, and fairly long cardinal process buttressed by strong ridge joining or surrounding proximal end of brevisseptum, in latter case producing three ridges near midvalve. Lateral ridges strong and elevated, uniting with strong ear baffles to form marginal shelf around entire visceral disc, shelf looping sharply posteriorly toward distal end of brevisseptum. Anterior edge of shelf with numerous small spines. Adductor field large, formed of two triangular patches on each side of brevisseptum, anterior angle of each triangle forming nondendritic adductor, remainder of triangle strongly dendritic. Brachial ridges not developed.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 702c, 703c, 707e, 710u, 710z, 721r, 724b, 724j.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 707e							
YPM 10767 (holotype)	19.0	14.0?	37.0	?	24.5	13.5?	?
149872a	19.7	15.2	35.0	30.4*?	26.8	13.0	6.9
149872b	22.5	16.5	41.0	26.6*	22.4	14.3	9.1
149872c	21.0	15.4	37.5	23.4*?	24.8	13.7	6.3
149872d	18.7	13.0	40.0	26.2*	23.2	13.2	8.6
149872e	18.6	14.3	40.0	?	23.4	13.3	8.0
149872f	24.0	15.2	45.0	26.6*?	27.8	15.9	10.6
149872g	20.9	15.6	37.0	?	24.3	13.2	7.5
149872h	24.2	?	39.0	24.0?	24.0	11.0	?
149872i	21.6	16.0	38.0	?	24.3	14.0	8.0
149872j	19.8	15.8	40.0	31.2*?	29.0	13.4	7.5
149872k	21.0	17.3	37.0	28.6*?	28.4*	13.5	5.0
149872l	28.5	19.8	45.0	34.0*	31.0*	13.7?	8.0

**DIAGNOSIS.**—Strongly sulcate and nasute *Kutorginella* having two long trail spines and two long lateral spines.

**TYPES.**—Holotype: YPM 10767. Figured hypotypes: USNM 149871a–e; 149872e, h, l–o; 149879. Measured hypotypes: USNM 149872a–l.

**COMPARISON.**—The few large halteroid spines are distinctive of this species and separate it easily from *Thamnosia anterospinosa* Cooper and Grant, which is multispinose, and from *Kutorginella uddeni*, which has a curved ring of spines on the lateral slopes. Comparison is thus left with *K. umbonata* (Muir-Wood and Cooper), which also has a few large halteroid spines on the lateral slopes and trail. The latter, however, is a larger and more robust species than *K. sullivanensis* (R. E. King), with a higher umbonal region, more broadly rounded lateral profile, and usually more numerous halteroid spines; moreover, *K. sullivanensis* is more sharply nasute and with less strongly developed broad plication of the trail.

**DISCUSSION.**—*Kutorginella sullivanensis* is fairly common in the bituminous limestone on the long bench just south of Sullivan Peak. Many specimens are somewhat flattened from umbo to trail but nevertheless seem normally depressed. A few specimens preserve the exceptionally long halteroid spines that give a clear indication of the way in which the species must have lived on the sea bottom.

Brachial interiors are usually fairly well preserved but the brachial ridges are preserved only in four specimens. They extend anterolaterally from the adductor field and are looped near to the lateral base of the flange. In this species the lateral flange is unusually wide and is set at a high angle to the visceral disc surface. The area surrounding the adductor field is finely pitted. The cardinal process is generally small and narrowly compressed.

### *Kutorginella uddeni*, new species

PLATE 343: FIGURES 1–17

Medium to large for genus, transversely subrectangular in outline; hinge forming widest part; ears prominent, flattened. Lateral margins gently rounded; anterior margin broadly rounded, usually faintly indented medially. Profile plano-convex with brachial valve strongly geniculated. Surface of both

valves costellate, pedicle valve spinose; visceral region marked by distant concentric undulations crudely cancellating the costellae; trail with about five costellae in 5 mm near anterior margin. Brachial valve with numerous concentric rugae about same width as costellae, producing fine and prominent reticulation. Spines numerous on pedicle valve: few spines along posterior margin; row of five or six curving over ears at base of lateral slopes; few oblique spines on visceral disc; numerous spines scattered over trail and arising from costellae; no spines seen on brachial valve.

Profile unevenly convex, greatest convexity at venter about midvalve, umbonal region slightly curved, trail gently convex. Anterior profile forming broad medially depressed dome. Umbonal region strongly inflated and with steep slopes to lateral extremities. Median region strongly inflated and humped. Sulcus originating on visceral disc, fairly narrow, usually shallow and extending to anterior margin. Flanks bounding sulcus moderately inflated and with steep sides.

Brachial valve nearly flat for about two-thirds of length, there abruptly geniculated to form nearly vertical slopes. Trail long and strongly costellate. Umbonal region shallowly depressed. Ears flattened and demarcated by oblique flexure toward pedicle valve. Fold barely perceptible, originating near midvalve.

Pedicle valve interior with small adductor platform and large flabellate diductor scars. Ears flattened and without baffles.

Brachial valve interior with narrow cardinal process deeply indented on ventral side, trilobed on dorsal side, median lobe bent posterodorsally. Cardinal process buttressed by thickening surrounding proximal end of brevisseptum. Lateral ridge low, joining large ear baffles continuous anteriorly to anterior end of visceral disc. Adductor scars not strongly thickened. Posterolateral areas pitted. Anterior of visceral disc with small endospines. Brachial ridges not seen.

**STRATIGRAPHIC OCCURRENCE.**—Gaptank Formation (*Uddenites*-bearing Shale Member), Neal Ranch Formation, Lenox Hills Formation.

**LOCALITIES.**—Gaptank: USNM 701y. *Uddenites*: 701e, 701p, 701q, 701t, 701v, 702n, 703–l, 721h, 721i. Neal Ranch: 701, 701c, 715b. Lenox Hills: 707m, 713y, 715, 720z.

**DIAGNOSIS.**—*Kutorginella* with a row of spines

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 701q							
149866a	22.3	?	43.0	29.8?	29.5	13.0?	?
149866b	20.0	?	39.0	26.0*	27.3	13.0	?
149866c	21.0	13.7	42.0	?	?	14.6	11.0
USNM 701e							
149857a	25.6	?	50.0?	32.4?	29.2	15.0	?
USNM 701							
149855a	22.8	16.0	43.0	26.4?	27.3	15.2	6.0+
(holotype)							
USNM 721i							
149865a	20.4	15.4	36.0?	?	30.0	13.3	9.2

curving at the base of the lateral slope from the umbo to the posterolateral extremity.

**TYPES.**—Holotype: USNM 149855a. Figured paratypes: USNM 149857a, 149866a, 153906a, b. Measured paratypes: USNM 149857a, 149865a, 149866a–c. Unfigured paratypes: USNM 149866b, c; 153906a.

**COMPARISONS.**—This, like other Glass Mountains species of *Kutorginella*, has a row of halteroid spines over the ears extending from the umbo to the posterolateral extremity. In this respect it is like *K. lasallensis* (Worthen) of the Pennsylvanian and is probably closely related to it. It differs from that species in having a fuller and more rounded lateral profile, longer and more curved trail, the umbonal region less extended posterior to the hinge, and more swollen median region.

**DISCUSSION.**—Specimens of *Kutorginella* are fairly common in the *Uddenites*-bearing Shale Member of the Gaptank Formation, but it is difficult to find them favorably mineralized in limestone.

### *Kutorginella umbonata* (Muir-Wood and Cooper)

PLATE 343: FIGURES 18–33; PLATE 344: FIGURES 1–30

*Retaria umbonata* Muir-Wood and Cooper, 1960:231, pl. 70: figs. 1–15.

Large for genus, transversely elliptical to subrectangular in outline; hinge forming widest part; ears large, narrowly rounded, moderately to strongly convex. Sides rounded, sloping medially. Anterior margin broadly rounded and broadly plicated. Both valves costellate and spinose. Visceral disc slopes with few strong rugae crudely cancellating the cos-

tellae; four to six costellae per 5 mm on trail; costellae variable, in some specimens increasing in width anteriorly and becoming broad and flattened, but in others increasing in number at front by intercalation. Spines of two sizes: small, with elongate bases on visceral disc and posterior; and large halteroid spines on lateral slopes and trail. Halteroid spines forming row of five increasingly large stout spines from base of lateral slope over ear around anterior margin of trail to opposite ear; row of five spines at base of lateral slopes and overhanging ear, last and largest spine in this row forming first spine of horizontal row; ears spineless or with few small spines. Brachial valve with numerous rugae inside ears and with numerous, delicate, long scattered spines on entire shell, including ears.

Pedicle valve with narrowly humped lateral profile, visceral disc region short and fairly strongly rounded, trail region about twice length of visceral disc and moderately rounded. Anterior profile broad dome, with steep sides and indented deeply in middle. Visceral disc moderately inflated and with steep lateral slopes; median region inflated. Sulcus originating on umbonal region, deep and wide but deepest in middle; flanks bounding sulcus in posterior and median regions strongly rounded and inflated, anterior becoming sulcate to form four depressions on anterior margin separated by shallow but narrow folds. Median pair of folds bounding median sulcus prolonged somewhat and producing nasute projection.

Brachial valve nearly flat to slightly concave in posterior half but strongly geniculate in anterior half; place of geniculation narrowly rounded; umbonal region shallowly depressed; sulcus fairly prom-

inent, originating just anterior to umbonal pit and extending to front margin. Ears fairly strongly concave, marked by narrow oblique flexure and narrow dorsal fold of anterior margin.

Pedicle valve interior with adductor field moderately elevated on median ridge formed by sulcus; ears wrinkled and with interior spines bordering their inner edges, inside and outside of ridge forming inner edge of ear. Trail slope coarsely pustulose to endospinose.

Brachial valve interior with cardinal process

long-shafted and slender in young, stout and long in old adults; myophore narrowly trilobed in young, thickened in old specimens, median lobe bent posteriorly. Buttress ridge, elevated and narrowly rounded. Lateral ridges strong, joining ear baffles and marginal shelf, this widest at sides but extending as ridge of spines across anterior of visceral disc; marginal shelf edge serrated. Trail slope pustulose. Adductor field with two reniform patches, posterior pair strongly dendritic. Brachial ridges indistinct.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702c							
124044b	28.0	20.0	49.0	32.0*?	30.0	17.3	9.0
(holotype)							
124044c	28.5	21.5	59.0	42.3	35.4	18.2	10.0
149880a	24.5	20.0	53.0	39.8	34.0	16.7	9.0
149880b	25.4	18.0	49.0	33.2	30.0	16.1	9.1
149880c	27.1	18.4	54.0	36.8	30.5	16.8	9.7
149880d	26.8	19.0	53.0	37.4	28.4	18.4	9.5
149880e	31.0	21.6	58.0	44.0*	32.4	17.8	9.6
149880f	27.5	18.4	51.0	40.0*	32.5	17.6	10.4
149880g	13.7	12.4	19.0	10.7	17.8	4.8	3.4
149880h	11.7	10.5	15.0	9.1	12.3	4.7	2.9

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation, Road Canyon Formation.

LOCALITIES.—Cathedral Mountain: USNM 721u. Road Canyon: AMNH 507; USNM 702c, 703, 703a, 703b, 703d, 712t, 719x, 732i, 732j, 736x.

DIAGNOSIS.—Large *Kutorginella* having anterior margin thrown into broad plication.

TYPES.—Holotype: USNM 124044b. Figured paratypes: USNM 124044a, c–e, h, m, n. Unfigured paratypes: USNM 124044e–g, i–l, n. Figured hypotypes: USNM 149879a, b; 153907a–g. Measured paratypes: USNM 124044c. Measured hypotypes: USNM 149880a–h. Unfigured paratypes: USNM 124044g, i–l.

COMPARISON.—*Kutorginella umbonata* is compared with *K. sullivanensis* (R. E. King) the species closest to it, under that species heading.

DISCUSSION.—Specimens of *K. umbonata* are fairly common in the Road Canyon Formation at USNM 702c, where they are exceptionally well preserved. The external characters of most importance in this species are the long trail, and the broad plication of

the anterior, which is a consequence of it. Specimen USNM 149879b is decidedly trilobed, the nasute median prolongation forming a long anterior lobe and a strong fold anterior to each ear forming lateral lobes.

Inside the brachial valve the flange appears to be widest anterior to the ears but the flange is not extended far over the trail slope. The anterior edge of the flange, however, is strongly spinose, the spines forming an effective screen across the gape. In old specimens the adductor field is fairly strongly thickened and the area around it minutely pitted.

Genus *Thamnusia* Cooper and Grant, 1969

*Thamnusia* Cooper and Grant, 1969:10.

Fairly large subrectangular outline, hinge wide, large extended ears. Deeply plano- to concavo-convex, pedicle valve strongly swollen but brachial valve with flat visceral disc and sharply geniculated trail. Anterior commissure with slight dorsad fold. Cos-



tellae narrowly rounded; visceral disc of both valves reticulated by interruption of costellae by regular concentric undulations. Spines numerous, usually thin and long; many small spines on ears; thick brush of spines on posterolateral slopes over ears; numerous halteroid spines on trail and anterolateral slopes; median region marked by short, delicate, scattered spines. Brachial valve with numerous hairlike scattered spines.

Pedicle valve interior with more-or-less strongly elevated adductor track and widely flabellate adductor scars not enclosing adductors; ear baffle narrow, thin oblique ridge on edge of ear trough.

Brachial valve interior with variable cardinal process, bilobed in young and elongated, becoming stout and trilobed in adult; cardinal process buttress long and slender, uniting with weak brevisseptum. Lateral ridges forming flattened flanges anterolaterally, extending to anterolateral extremities, there forming row of spines at midvalve. Brachial ridges laterally extended and with broad loop, but usually weakly formed.

TYPE-SPECIES.—*Thamnosia anterospinosa* Cooper and Grant (1969:10, pl. 5: figs. 26, 27).

DIAGNOSIS.—Like *Kutorginella*, but with a thick brush of spines on the lateral slopes rather than a single row of spines.

COMPARISON.—This genus need only be compared with *Kutorginella*, of which it is an aberration characterized by a thick brush of spines on the lateral slopes over the ears.

DISCUSSION.—This genus has in the Glass Mountains four species which are like *Kutorginella* (= *Retaria*) except for the spine arrangement. *Thamnosia parvispinosa* (Stehli) has numerous spines on all parts of the shell except the venter; and this is true also of *T. anterospinosa* Cooper and Grant, which has stronger spines than those of the Sierra Diablo species. The interior details are like those of *Kutorginella*, and the cardinal process shows the same kinds of variation.

This genus is also well represented outside of the Glass Mountains. *Productus capitanensis* Girty, with its high internal lateral flange, belongs here; it is also unusual for the development of a strongly nasute anterior suggesting *Kutorginella*. The Mexican species *Dictyoclostus depressa* Cooper, which has a very high lateral flange on the interior of the brachial valve, certainly belongs in this genus. The same is true of *Productus arcticus* Whitfield,

an Arctic species that strongly resembles *T. phragmophora*, new species, of the Glass Mountains.

### *Thamnosia anterospinosa*, Cooper and Grant

PLATE 348: FIGURES 1–19; PLATE 349: FIGURES 1–5

*Thamnosia anterospinosa* Cooper and Grant, 1969:10, pl. 5: figs. 26, 27.

Moderately large for genus, transversely rectangular in outline, hinge equal to midwidth or forming widest part. Sides gently rounded; anterior margin broadly rounded and slightly indented anteriorly. Ears broad and flat. Cross section planoconvex, anterior of brachial valve abruptly geniculated near midvalve of large adults. Surface of both valves costellate and spinose. Visceral region with few concentric wrinkles on slopes; posterior margin wrinkled just inside ears; costellae rounder and more sharply defined on visceral disc region and modified by elongate spine bases; costellae on trail broad, flatly convex, and separated by fine striae, four to five costellae per 5 mm on trail. Spines numerous; in thick brush of long, stout spines around base of lateral slopes; short spines arising at low angle on visceral disc; median part of trail nearly devoid of spines, but anterior third with thick concentration of long, stout spines. Brachial valve with a concentration of rugae just inside ears but dying out anteriorly; spines numerous, long, delicate, and hairlike.

Pedicle valve fairly evenly convex in lateral profile, median region broadly humped, visceral region shorter and somewhat flatter than trail. Anterior profile highly domed, with steep sides and medianly depressed median region. Umbonal and visceral regions moderately swollen, but sides with long slopes; median region strongly swollen; sulcus originating on umbonal region, shallow, moderately broad, extending to anterior margin, where it is fainter. Flanks moderately rounded and steep-sided.

Brachial valve nearly flat, umbonal region shallowly depressed. Geniculation strong and angular, near midvalve of large adults. Ears flat, bent sharply toward pedicle valve. Fold low and inconspicuous originating near middle of visceral disc.

Pedicle valve interior with adductor field elongated and slightly elevated. No ear baffles.

Brachial valve with elongated cardinal process, strongly trilobed in adult; cardinal process but-

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702un							
149852	27.0	21.3	59.0	36.4*	32.0	18.0	11.0
(holotype)							
155131a	30.3	22.0	59.0	42.0*	33.3	17.3	10.7
155131b	24.1	19.6	48.0	26.6*	28.4	16.3	9.6
155131d	22.8	17.2	47.0?	?	27.3	16.0	12.0

truss rounded, elevated, and continuous with brevisseptum extending to anterior edge of visceral disc. Lateral ridge strong, uniting with ear baffles to form marginal elevation around entire visceral area; ridge widest on sides, overhanging valve edge there. Adductor field large, anterior scars small and slightly elevated, lateral scars strongly dendritic, large and subtriangular. Brachial ridges large but faintly developed.

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITIES.—USNM 702, 702ent, 702-low, 702un, 703b, 707q, 721u, 724s, 726y.

DIAGNOSIS.—Large *Thamnosia* with long spines around the anterior and lateral margins, few on the median part of the trail.

TYPES.—Holotype: USNM 149852. Figured hypotypes: USNM 154021a, b; 154022a, b; 155131b, e, f; Measured hypotypes: USNM 155131a, b, d.

COMPARISONS.—This species is multispinose, consequently cannot be compared with sparsely spinose types such as *Kutorginella sullivanensis* (R. E. King) and *K. umbonata* (Muir-Wood and Cooper). It is also easily distinguished from *K. uddeni*, new species, which has a row of spines at the base of the lateral slopes.

*Thamnosia anterospinosa* resembles externally *T. silicica*, new species, in having a fringe of thin spines extending from just anterior to the ears to midvalve, and also in possessing a tuft of spines over the ears on the lateral slopes. The resemblance between the two, however, ends in this superficial likeness. *T. silicica* is larger, broader, more distinctly reticulate on the pedicle valve, and has fine costellae. The spines of *T. silicica* are more delicate than those of *T. anterospinosa* although the former is a much larger species. The lateral profile of *T. silicica* is more rounded than that of *T. anterospinosa* because tangents to the visceral disc and

trail are approximately parallel. In addition, the sulcus of *T. silicica* is wide and deep, much more so than that of *T. anterospinosa*, and the trail is strongly nasute, more so than in any specimens of *T. anterospinosa*.

The Sierra Diablo species *T. parvispinosa* (Stehli) is multispinose, but its spines are much more delicate than those of the Cathedral Mountain species.

DISCUSSION.—This is a rare species but has very well defined characters. The brachial valve is distinctive because of the unusually strong trilobation of the myophore in old specimens. The adductor field has the dendritic scars scarcely thickened, but the anterior non-dendritic scars are thickened and slightly elevated at their anterior end. The flange is widest laterally.

*Thamnosia capitanensis* (Girty)

PLATE 345: FIGURES 1–17; PLATE 349: FIGURES 6–19

*Productus semireticulatus* Shumard (not Martin), 1858:292.  
*Productus semireticulatus* var. *antiquatus* Shumard (not Martin), 1859:389.

*Productus semireticulatus* var. *capitanensis* Girty, 1909:254, pl. 12: figs. 1–3b, pl. 20: figs. 8, 8a.—King, 1931:66, pl. 10: fig. 15.

Large, transversely rectangular in outline, hinge forming widest part; ears laterally extended; sides slightly divergent; anterior strongly nasute. Valves deeply concavo-convex and strongly depressed, surface of visceral disc nearly parallel to surface of trail. Surface costate and costellate, visceral disc strongly reticulate, fine costae cancellated by strong concentric rugae; trail posteriorly costate to costellate and anteriorly finely costellate. Spines thin and delicate, forming row on lateral slope terminating in thick tuft at base of ears.

Pedicle valve lateral profile very narrowly curved;

anterior profile high, broad, domed. Visceral disc region moderately swollen; angle of geniculation small; geniculated region very narrowly rounded. Sulcus originating near beak, deepening over venter, becoming shallower anteriorly but continuing to anterior margin as shallow, wide trough. Anterior quadrilobate, sulcus dividing nasute extension into two lobes and lateral flanks set off as lobes by sulcus on each side of nasute extension.

Brachial valve nearly flat in posterior half to one third, narrowly geniculated, at angle of 60°, with gently convex trail. Median fold low and narrow, developed chiefly on trail and scarcely visible on visceral disc.

Pedicle valve interior with elongate adductor field located on ridge produced by sulcus of exterior; muscle scars not strongly thickened.

Brachial valve interior with elongated cardinal process in young but short and stout in adults; posterior face trilobed; adductor field somewhat cordate in outline, thickened, and strongly dendritic. Brevisseptum slender and low; lateral flanges extremely high posterolaterally, descending rapidly anteriorly, terminating near place of geniculation.

MEASUREMENTS (in mm).—Thickness and brachial valve length unmeasurable.

	length	surface length	hinge width	midwidth	height
AMNH 475					
151481	26.1	70.0	43.0+	44.0	18.0?
USNM 738a					
151478a	35.2	70.0	53.0*	47.8	24.0?
151478b	27.3	66.0	46.0?	40.6	21.0?
151478c	29.8	72.0?	46.6	45.3	21.5

STRATIGRAPHIC OCCURRENCE.—Capitan Formation, Bell Canyon Formation (Hegler, Pinery Rader, and Lamar members).

LOCALITIES.—Capitan: USGS 2926 (green), 2930 (green); AMNH 475; USNM 740k, 740-l, 740m, 774, 847. USNM 725-l, 738a, 740, 748a, 750a. Hegler: AMNH 635; USNM 731, 732a, 740c, 740d. Pinery: AMNH 398, 401, 435, 537; USNM 725h, 725n, 733, 736. Rader: AMNH 401, 403, 410; USNM, 725f, 725g, 740a, 740h, 740i, 740j. Lamar: 725e, 728p, 737a, 738b.

DIAGNOSIS.—Large, strongly lobate and nasute *Thamnosia*.

TYPES.—Lectotype: USNM 118522. Paratypes: USNM 118521a-c. Figured hypotypes: USNM 151474a, b; 151478b; 151481; 154017a, b; 154023,

154024. Measured hypotypes: USNM 151478a-c, 151481.

COMPARISON.—This is one of the largest species of *Thamnosia* and is best compared to *T. silicica*, new species, which approaches it in size and has a strong nasute anterior. The Capitan species is much more strongly reticulate on the visceral disc than the Taylor Ranch species, is more strongly ornamented, and much more lobate anteriorly. The strong lobation, nasute extension, and strong ornament are ready means of distinction between this species and other species of *Thamnosia*.

DISCUSSION.—Few silicified specimens of this species have been taken. In the Guadalupe Mountains it is difficult to obtain the larger species well silicified; however, a fair number of good brachial valve interiors have been obtained from the dark limestones of the Bell Canyon Formation. No good pedicle valves were found. It is difficult to determine the spine arrangement of the specimens preserved in the white limestone, consequently search for good specimens of the pedicle valve has been made to no avail and the spine arrangement of the species is uncertain.

### *Thamnosia parvispinosa* (Stehli)

PLATE 346: FIGURES 1-6; PLATE 347: FIGURES 1-30

*Alexenia?* *parvispinosa* Stehli, 1954:325, pl. 22: figs. 20-22; pl. 23: figs. 1, 2.

Usual size for genus, wider than long, strongly swollen pedicle valve and strongly geniculated brachial valve; sides somewhat narrowly rounded; anterior margin narrowly emarginate medially; anterior commissure with slight dorsad wave. Umbonal region strongly swollen. Surface costellate; umbonal region faintly reticulated; costellae numbering about eight per 10 mm at front of large valve. Spines, fine, slender, fairly long, numerous; small spines on ears; brush of fine, long, slender spines on lateral slope over ears; scattered short spines on visceral disc and posterior part of trail; stouter longer spines fairly strongly concentrated on anterior part of trail, about same strength as those forming brush over ears. Brachial valve with numerous long spines especially on trail, but also scattered over whole surface. Flattened posterior reticulated.

Pedicle valve fairly evenly and strongly convex

in lateral profile; anterior profile broadly but highly domed with middle notched. Umbonal region swollen and with steep lateral slopes; geniculated area broadly rounded; trail long, convex, and steep. Sulcus originating on umbonal region, narrow and shallow, extending to front margin, but in some large and old specimens flattening at front, suggesting nasute extension.

Brachial valve broadly flat for about  $\frac{3}{4}$  of length then abruptly geniculated nearly at right angle to produce short trail. Umbonal region depressed. Ears flattened.

Pedicle valve interior with flattened ears, inner edge forming low fluted baffle. Muscle scars only slightly impressed.

Brachial valve with highly variable cardinal process, ranging from long, narrow, and slender to short and stout. Shaft buttress poorly developed and forming low, narrow ridge uniting with vestigial brevisseptum. Muscle scars lightly impressed, strongly dendritic. Brachial ridges scarcely visible. Flange moderately strong, best developed laterally.

MEASUREMENTS (in mm).—Thickness of specimen 152726a is 12.0; of others, unmeasurable.

	<i>length</i>	<i>brach- ial valve length</i>	<i>sur- face length</i>	<i>hinge width</i>	<i>mid- width</i>	<i>height</i>
USNM 728e						
152726a	25.7	19.0	48.0	25.2?	32.0?	16.5
152726b	27.5	?	52.0	30.0	35.0?	17.0
152726c	?	20.8	?	23.8	31.0	?

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation, Skinner Ranch Formation (Decie Member).

LOCALITIES.—Bone Spring: AMNH 625, 629; USNM 725c, 728e, 728f, 728h, 728t. Decie Ranch: 707a. Skinner Ranch (base): 720e.

DIAGNOSIS.—Large *Thamnosia* with numerous small and delicate spines.

TYPES.—Lectotype: AMNH 27307/1:2. Paratypes AMNH 27307/1:1, 27307/1:3, 27307/1:4. Figured hypotypes: USNM 149890a; 149893; 152726a, b; 154018a, b; 154019a–d; 154020. Measured hypotypes: USNM 152726a–c.

COMPARISON.—This species is characterized by its moderate size and the delicacy of its spines, features that distinguish it from *T. anterospinosa* Cooper and Grant (1969).

DISCUSSION.—The flattening of the median anterior part of the pedicle valve of this species suggests a tendency toward a nasute extension, however, none of the specimens in the collection actually develops such an extension. This species is fairly consistent in the development of its spines, but the variation in the brachial valve is considerable. The cardinal process varies from very narrowly elongated to short and stubby. The most extremely narrow phase shows the characteristic median depression on the distal end of its ventral face. The narrow process is bilobed but the stouter ones are clearly trilobed in ventral view and some have the median depression. A few specimens obliterate the median depression, and some are so short and stout that they would have to be described as sessile. The posterior faces of most of them are trilobed, with an extended median lobe pinched between two lateral lobes, a modification of the marginiferid cardinal process. The specimen with a long narrow process is dorsally bilobed.

Other interior details are also variable. In some the buttress to the cardinal process shaft is strong and well developed, but in most of them it is very weak. The marginal flange is seldom wide and is best seen in the midlateral region.

No type was designated by Stehli (1954); we, therefore, select the specimen on his plate 22: figure 21 as lectotype. This shows the lateral concentration of fine spines and the brush over the ears.

### *Thamnosia phragmophora*, new species

PLATE 316: FIGURES 52–56, PLATE 346: FIGURES 7–19

*Productus arcticus* R. E. King (not Whitfield), 1931:66, pl. 10: figs. 16, 17.

Fairly large, transversely rectangular in outline, hinge forming widest part; ears large and extended. Sides gently rounded; anterior margin broadly rounded and medially nasute. Surface semireticulate, visceral disc of both valves fairly coarsely marked; trail finely costate, costae irregular in size, finest in sulcus and numbering about six per 10 mm. Spines numerous; in band of fairly thick halteroid spines overhanging spineless ears, located on lateral slopes and posterior margin at base of umbonal slopes; fine body spines on nodes of visceral

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706d							
151462a	29.0	19.4	80.0	56.0*	47.3	27.0	14.7
151462b	33.4	21.8	72.0	64.2*	45.6	26.8	19.3
(holotype)							
151462c	29.1	20.5	70.0	55.2*	45.8	24.8	16.0

disc formed by intersection of the rugae and costae. Brachial valve with scattered, long, slender spines.

Pedicle valve with narrowly convex lateral profile, posterior third of visceral disc region somewhat flattened, anterior third moderately convex, median third forming geniculated area. Anterior profile high, rounded, domed, medially indented, and with precipitous sides. Umbonal region flatly convex, with moderately sloping umbonal slopes to ears; median, or geniculated, region swollen. Sulcus originating on anterior side of umbonal region, narrow and fairly deep, continuing to anterior margin, there becoming shallow in old specimens. Flanks of young adults narrowly rounded, sulcate in old specimens and forming flattened nasute extension.

Brachial valve deeply concave, but with flattened to slightly concave and strongly reticulated visceral disc. Geniculation sharp and producing precipitous sides and anterior. Ears large, concave, and well demarcated but with tendency to break off at baffles. Median fold originating on anterior side of shallow umbonal depression, broadly carinate and moderately elevated.

Pedicle valve interior with broadly flabellate diductor scars; adductor field slightly thickened in posterior part, scars strongly dendritic.

Brachial valve interior with narrowly compressed, elongate but trilobed cardinal process, moderately developed lateral ridges but strong and high ear baffles; adductor field not thickened and scars strongly dendritic; brevisseptum strong. Anterior trail slope marked by small endospines.

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank and Appel Ranch members, and lens below Appel Ranch).

LOCALITIES.—China Tank: USNM 733q. Appel Ranch: USNM 706d, 714o, 715i, 719z, 727j. Lens: USNM 742b.

DIAGNOSIS.—Large *Thamnosia* strongly depressed,

anteriorly nasute, and with numerous small trail spines.

TYPES.—Holotype: USNM 151462b. Figured paratypes: USNM 151462a, c, d; 153847. Measured paratypes: USNM 151462a, c.

COMPARISON.—This large species strongly suggests *T. capitanensis* (Girty). The two are of about the same size, but *T. capitanensis* is more strongly lobate anteriorly and less spinose on the trail and visceral disc region. Furthermore, the visceral disc of the Guadalupe species is more strongly swollen and more coarsely reticulated.

DISCUSSION.—This is a rare species, found usually somewhat crushed and seldom in good condition. We have no specimens that show the entire nasute extension.

*Thamnosia silicica*, new species

PLATE 351: FIGURES 1–18

*Productus hessensis* R. E. King, 1931:68, pl. 11: fig. 5 [only].

Large for genus, transversely subrectangular in outline; hinge equal to midwidth or forming widest part; ears large and flattened. Sides somewhat narrowly rounded; anterior margin broadly rounded to broadly nasute. Cross section, plano-convex, anterior of brachial valve strongly geniculated. Surface wrinkled, costellate, and both valves spinose. Visceral disc region with strong, narrowly rounded concentric undulations concentrated on lateral slopes and causing crude reticulation; trail without wrinkles and marked by slender costellae separated by striae, four to five per 5 mm on median and anterior parts of trail. Brachial valve with visceral disc region more finely and distinctly reticulated. Spines mostly slender: fine spines along posterior margin and on visceral disc region and lateral slopes; large tuft or band of thicker erect spines



on lateral slopes of shell body and ears; numerous fine spines on trail confined to costellae. Brachial valve with numerous long, erect and delicate spines over whole surface.

Pedicle valve strongly and narrowly humped near midvalve, visceral region moderately convex; anterior profile high, wide, domed, with nearly vertical sides, top medially indented. Umbonal and visceral region moderately swollen, with fairly steep lateral slopes. Median region greatly inflated. Sulcus originating on umbonal region, deepest medially but broad and affecting about half of valve

width. Trail long, anteriorly drawn into long blunt and flattened nose medially depressed by sulcus. Flanks bounding sulcus moderately swollen and with steep sides.

Pedicle valve interior unknown. Brachial valve interior with fairly large and erect cardinal process buttressed by long, slender, rounded ridge continuous with high and thin brevisseptum. Adductor field long and narrow, posterior scars narrow but strongly dendritic. Ear baffle strong and continued anteriorly and medially as thickening around anterior margin of visceral disc.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702f							
151469	32.8	?	60.0	47.7?	42.0	21.5	?
USNM 702e							
151468a	35.3	?	64.0	54.0*	42.0*	21.0	?
151468b	30.6	19.6	60.0	45.0*	40.4	18.5	12.8
(holotype)							
USNM 702m							
151470	24.5	19.8	44.0?	41.2	38.0	14.4	7.6

STRATIGRAPHIC OCCURRENCE.—Hess Formation (fossil bed of P. B. King = Taylor Ranch Member).

LOCALITIES.—USNM 702d, 702e, 702f, 702m, 716n, 716o, 722p.

DIAGNOSIS.—Small, broadly sulcate and broadly nasute *Thamnosia* having numerous, delicate spines on the lateral slopes.

TYPES.—Holotype: USNM 151468b. Figured paratypes: USNM 151468a, 151469, 151270. Measured paratypes: USNM 151468a, 151469, 151470.

COMPARISON.—This species is compared with *T. anterospinosa* Cooper and Grant (1969) under that species. It is not comparable to any other species from the Glass Mountains.

DISCUSSION.—This is not a common species and has only been found in the Taylor Ranch Member of the Hess Formation in localities that are all near together. It is one of the largest species of this genus yet found. Its preservation is not favorable for extraction by the acid technique because of the highly siliceous character of the matrix.

#### *Thamnosia* species 1

Large, exact outline not clear but probably rec-

tangular and with greatest width at hinge; ears large. Margins not known. Surface costellate, costellae numbering about four per 5 mm on trail; costellae of visceral disc cancellated and with elongated spine bases; costellae at edge of visceral disc increasing by intercalation. Spines small; numerous on flanks; short, slender, and slightly curved on visceral disc. Trail spines not known.

Pedicle valve with unevenly convex lateral profile; sulcus originating near umbonal region, deep and wide; geniculation moderately strong. Interior with elongated but narrow adductor field. Ear baffle thick, elevated, granulose, and spinose.

Brachial valve flatly concave, sharply geniculated anteriorly, strongly reticulated and pitted; fold originating just anterior to umbonal depression, low, and poorly defined. Cardinal process stout-shafted, trilobed, with lateral lobes pinched together over median lobe; adductor field with triangular, dendritic posterior scars and small, nondendritic anterior scars. Cardinal process buttress ridge thick. Lateral flange or marginal ridge erect at ears but low on anterolateral areas and anterior; endospines small.

Described specimens: USNM 155033a-f.

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank Member).

LOCALITY.—USNM 706c.

DISCUSSION.—This species is definitely aberrant for the genus. Inside the pedicle valve the ear is crossed by an unusually high and strong baffle, a feature not seen in other species. In the brachial valve the flange is low and is scarcely visible across the anterior edge of the visceral disc. The cardinal process is unusually stout and the adductor scars fairly strongly elevated.

### Family ECHINOCONCHIDAE Stehli, 1954

Productacea having a deep body cavity, strongly umbonate pedicle valve, and a long shafted, dorsally curved cardinal process in the flattened brachial valve; cardinal process with anteriorly bilobed but posteriorly trilobed myophore.

### Subfamily ECHINOCONCHINAE Stehli, 1954

Echinoconchidae having the valves covered by abundant, short spines of two or more series, or spine ridges bearing spines either scattered over the surface, or arranged on concentric bands, or on rugae.

Genera in West Texas: *Echinaria* Muir-Wood and Cooper, 1960, *Calliprotonia* Muir-Wood and Cooper, 1960, and *Bathymyonia* Muir-Wood and Cooper, 1960.

*Echinaria* is very rare and confined to Lower Wolfcampian rocks. Other members of the family except *Bathymyonia* occur in older rocks; *Bathymyonia* occurs in the Park City Formation and should be sought in the Word and Cherry Canyon formations. *Calliprotonia* is very rare and is represented by only a few specimens.

### Genus *Echinaria* Muir-Wood and Cooper, 1960

*Echinaria* Muir-Wood and Cooper, 1960:248.—Williams et al., 1965:H485.

*Echinaria* is similar to *Echinoconchus* on the exterior but has strongly dendritic muscle scars on the interior. In the Glass Mountains this genus is rare and occurs in the lower part of the column, in the *Uddenites*-bearing Shale Member of the Gaptank Formation and in the Wolfcampian. It is less common in the latter than in the Gaptank. Further-

more, most of the specimens collected in the more than 30 years devoted to Glass Mountains work produced only a small handful of poorly preserved specimens.

It is important to note that this genus in the Glass Mountains is confined to the lower formations. The youngest member is from the Lenox Hills Formation. No specimens have been taken from higher than the Lenox Hills in the Glass Mountains.

### *Echinaria* cf. *E. moorei* (Dunbar and Condra)

PLATE 386: FIGURES 14–17

cf. *Echinoconchus moorei* Dunbar and Condra, 1932:209, pl. 24: figs. 1–5.

Moderately large, elongate oval outline, hinge narrower than midwidth, ears small. Sides well rounded; anterior margin narrowly rounded. Surface unknown except for trace of regular and even surface lamellation. Spines not preserved.

Pedicle valve in lateral profile longitudinally moderately curved except for strongly and narrowly curved umbonal region; anterior profile broadly domed, depressed medially but with short, steep sides. Umbo narrowly swollen and with long beak; venter strongly swollen; trail moderately convex. Sulcus originating on umbonal region, broad and shallow and extending to anterior margin. Flanks bounding sulcus moderately rounded.

Brachial valve shallow, deepest on sides at mid-valve; sides moderately steep; fold low and broad, originating just anterior to umbonal depression. Ears not well differentiated.

Brachial valve interior with stout, curved cardinal process and strong lateral ridges.

Figured specimens: USNM 149680a, b; 153841.

MEASUREMENTS (in mm).—From locality USNM 701f, specimen 149689b: length 63.2, brachial valve length 51.4, surface length 110.0?, hinge width 42.8\*, midwidth 57.6, height 24.4, thickness 18.4.

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale member), Neal Ranch Formation.

LOCALITIES.—Gaptank: USNM 700g, 730m. *Uddenites*: 701f, 701p, 702n, 702q, 703–l, 703o. Neal Ranch: 713k.

DISCUSSION.—The identification of this species is based on comparison with specimens of *E. moorei* Dunbar and Condra from the Wayland Shale of

north-central Texas and the Topeka Shale from Kansas. Specimens from north Texas are generally larger than those from Kansas but conform to Dunbar and Condra's description in other respects. The pedicle valve of a specimen from the Wayland Shale, 1.2 miles south of Gunsight, Texas, definitely has three or four rows of spines on the lamellae, but evidence of a fifth row of small spines is not clear. The Glass Mountains specimens are not sufficiently well preserved to show such detail but in size and form they accord well with specimens from the Wayland Shale.

### *Echinaria species 1*

PLATE 445: FIGURES 1-8

Small, subtriangular to suboval in outline, length and width about equal; sides rounded; anterior margin broadly rounded; hinge narrower than midwidth. Ears small. Surface with broad concentric lamellae, each lamella marked by three to five rows of spines, stronger and larger spines occupying posterior rows. Spine rows staggered so that spines of one row lie opposite spaces between spines of adjacent rows. Ears and posterior margin marked by concentration of slender halteroid spines. Brachial valve marked like that of pedicle valve.

Pedicle valve evenly and moderately convex in lateral profile but umbonal region narrowly curved; anterior profile narrowly domed with steeply sloping sides. Umbonal region narrowly swollen and expanding to swollen venter. Trail broadly convex. Sulcus originating on umbonal region, narrow and shallow posteriorly, widening anteriorly but shallow throughout. Flanks moderately but narrowly rounded.

Brachial valve gently concave in median region; ears poorly demarcated. Sides sloping gently; umbonal region deeply depressed. Interior with strong lateral ridges and long median septum, thick and rounded posteriorly but slender and delicate anteriorly, reaching beyond midvalve. Cardinal process long-shafted, shaft inclined posterodorsally and expanding toward trilobed myophore. Adductor platform slightly thickened, dendritic.

Figured specimens: USNM 149682a-c.

MEASUREMENTS (in mm.).—From locality USNM 701, specimens 149682a and b (pedicle valves): respectively: length 30.1, 24.0; brachial valve length

25.6?, 19.6?; surface length 48.5, 35.5; hinge width 16.9?, 12.8; midwidth 31.0? ca. 20.0; height 13.6, 10.1; thickness indeterminate.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch and, Lenox Hills formations.

LOCALITIES.—Neal Ranch: USNM 701, 701c, 715e. Lenox Hills: 715.

COMPARISON AND DISCUSSION.—This is another small and variable species represented by few and inadequate specimens. The best specimens are from USNM 701 and well silicified but they are distorted and not complete. It is thus impossible to make a good specific description. All of these have a strong and deep sulcus on the pedicle valve.

The interior of the brachial valve from USNM 701 indicates a delicate species having a long median septum continuous with the buttress of the cardinal process. The latter is somewhat bilobed from the ventral side. Posteriorly it is trilobed and the median lobe is very large. Although the specimens appear to be adults it is not possible to be sure. Consequently, the species is not named.

### *Echinaria species 2*

Small, suboval in outline, length only slightly greater than width; hinge narrower than midwidth; sides rounded; anterior margin broadly rounded. Valves ornamented by regular concentric lamellae, evidence of several rows (up to five) of fine spines on each lamella.

Pedicle valve with moderately convex lateral profile, except for strongly convex umbonal region; anterior profile broad, gently and evenly rounded dome with steep sides. Umbonal region strongly and widely swollen; visceral region strongly swollen, but trail gently convex. No trace of sulcus.

Brachial valve shallowly and evenly concave, deepest near midvalve; sides short and steep posteriorly, less so anteriorly; anterior margin gently sloping, no fold. Ornament like that of opposite valve. Cardinal process long and slender.

Described specimen: USNM 149685.

MEASUREMENTS (in mm.).—From locality USNM 701u, specimen 149685: length 25.9, brachial valve length 19.4, surface length 43.0?, hinge width 18.8, midwidth 25.2, height 11.2, thickness 9.6?.

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member).

LOCALITY.—USNM 701u.

COMPARISONS.—This is a small species and appears to be an adult rather than the young of *E.* cf. *E. moorei* which occurs at other localities at this stratigraphic level. Absence of a median sulcus on the pedicle valve is an important difference from *E. moorei*. This feature also distinguishes it from *E. inexpectata* (Cooper) from the Permian of Oregon, which is comparable in size to the Glass Mountains specimens.

### Genus *Calliprotonia* Muir-Wood and Cooper, 1960

*Calliprotonia* Cooper and Muir-Wood, 1960:246.—Williams et al., 1965:H485.

#### *Calliprotonia* species

PLATE 386: FIGURES 10–13; PLATE 445: FIGURE 52

A small specimen from the Neal Ranch Formation at USNM 701d is placed here. The specimen is silicified, wider than long with narrow beak and narrow hinge. The pedicle valve is strongly convex and fairly deeply sulcate medially. The flanks are moderately rounded. The brachial valve is gently concave but with an anteromedian flattening. The surface of the pedicle valve is marked by 9 broad bands each with traces of several rows of spines. The cardinal process is small, erect, and the myophore faces dorsad.

Figured and measured specimen: USNM 149684.

MEASUREMENTS (in mm).—from locality USNM 701d, specimen 149684: length 16.0, brachial valve length 12.8, surface length 27.0, width 18.0, height 8.1, thickness 6.8.

### Genus *Bathymyonia* Muir-Wood and Cooper, 1960

*Bathymyonia* Muir-Wood and Cooper, 1960:244, 245.—Williams et al., 1965:H485.

Large usually ovate in outline, plano- to concavo-convex in profile, beak strongly arched. Body chamber deep and spacious. Hinge usually narrower than midwidth but equal to midwidth in some specimens. Anterior commissure with narrow dorsad wave. Pedicle valve sulcate; brachial valve with low, subcarinate fold. Entire surface spinose, spines of posterior third or half closely spaced and arranged

in quincunx, anterior two-thirds to half with regular concentric lamellae, each lamella bearing several rows of spines. Ears small, spinose, lateral slopes bearing dense brush of long delicate spines. Body spines variable in size, oblique, leaving shell at various angles, small ones scattered among larger, but all slender for large shells. Brachial valve covered by mat of spines, posterior half of shell covered by quincuncially arranged spines, anterior half with spines on concentric lamellae; spines leaving shell usually at fairly large angle and majority pointing anteriorly.

Pedicle valve interior with large flabellate diductor scars separated by long adductor track, strongly thickened in some specimens. No ear baffles.

Brachial valve with thick lateral ridges just anterior to posterior margin. Cardinal process long and erect, initially narrow, with subparallel or tapered sides and narrow myophore facing in dorsad direction. Median face of shaft longitudinally indented. Cardinal process expanded distally and trilobed in old adults and usually conspicuously bent in dorsad direction. Cardinal process buttressed by low, rounded median ridge uniting anteriorly with low, bladelike brevisseptum; buttress and ridge occupying long trough produced by dorsal fold. Adductor field long and narrow, scars strongly dendritic. Brachial ridges not preserved.

TYPE-SPECIES.—*Productus nevadensis* Meek (1877:64).

DIAGNOSIS.—Echinoconchidae having spines arranged densely in quincunx in the posterior third or half but in concentric bands on the anterior half or two-thirds.

COMPARISON.—This genus is like *Echinoconchus* in general form and profile but differs in the arrangement of the spines, which in *Echinoconchus* are arranged in bands over the entire shell. *Bathymyonia* has been mistaken for *Waagenoconcha* and has often passed under that name, but in that genus the entire surface is covered by spines arranged in quincunx. *Waagenoconcha* is further characterized by a broad anterior band with very fine spines, in contrast to the stronger ones on the main body of the shell (Grant, 1966b). *Bathymyonia* has no such anterior broad band of very fine spines.

DISCUSSION.—Although we have not found *Bathymyonia* with certainty in the Glass Mountains, figures are introduced here for comparison with *Waagenoconcha*, and because of the likelihood that

this genus will appear in the Glass Mountains in the higher parts of the Word Formation.

Our material from the Park City Formation permits some remarks on growth and anatomical details. The young pedicle valve of *Bathymyonia* strongly suggests a small adult *Waagenoconcha* except that it does not possess the band of smaller spines at the anterior. The small specimens are narrow-hinged and have narrow but swollen umbones. The shell is strongly and completely spinose; the spines are not differentiated but they are densest along the posterior margin and at the base of the posterolateral slopes. Development of concentric banding seems not to come at a uniform size.

The cardinal process seems to follow the same developmental pattern and variation as in *Waagenoconcha*. The youthful cardinal process is erect, standing at about a right angle to the hinge margin. It is ventrally and longitudinally divided by an impressed line; on the dorsal side the myophore at this stage is definitely trilobed, but the sides of the myophore are compressed, the median lobe being very narrow and the lateral lobes tightly squeezed against the median lobe to produce nearly parallel sides. In young adults the cardinal process is still erect and parallel-sided, but in old specimens it is bent dorsally at an angle to the hinge up to 45°. The old process has an expanded distal extremity, and the myophore is strongly trilobed. The collection has specimens showing retardation and acceleration of this development.

*Bathymyonia* appears to be characteristic of higher Word age faunas especially in the Phosphoria and Park City formations and in many places in the Canadian and European Arctic.

### *Bathymyonia nevadensis* (Meek)

PLATE 352: FIGURES 1-19; PLATE 353: FIGURES 12-18

*Productus nevadensis* Meek, 1877:64.

*Productus montpelierensis* Girty, 1910:30, pl. 2: figs. 5, 6.

*Waagenoconcha montpelierensis* (Girty) Cooper, 1953:42, pl. 13: figs. 6-14 [not figs. 1-5, = *Waagenoconcha* sp.].

DISCUSSION.—The illustrations introduced here are for comparison with *Waagenoconcha*. They show the difference in ornament between the two genera. Spines of the young and the young parts of adults are not differentiated, but are restricted to two bands at the anterior. The interiors of the two genera, however, are more nearly comparable.

Evidence that *Productus montpelierensis* Girty, and the Mexican specimens identified under that name by Cooper (1953), may be more properly classified with *Bathymyonia nevadensis* is given below in a discussion of "*Waagenoconcha montpelierensis*."

STRATIGRAPHIC OCCURRENCE.—Park City Formation (Franson Member, upper).

LOCALITIES.—USNM 760, 762.

TYPES.—Figured specimens: USNM 154034a-j, 154035a.

### Subfamily WAAGENOCONCHINAE

Muir-Wood and Cooper, 1960

Echinoconchidae with long, delicate, hairlike spines arranged in quincunx, occasionally springing from spine ridges, diminished in diameter in a band around the margin of the pedicle valve.

Genus in West Texas: *Waagenoconcha* Chao, 1927.

This genus appears first in the Graham Formation of north-central Texas, a formation now referred to the Pennsylvanian. In the Glass Mountains it appears first in the *Uddenites*-bearing Shale Member of the Gaptank Formation, a correlative, at least in part, of the Graham Formation. Because of the numerous Permian elements in this part of the Gaptank we are placing the *Uddenites*-bearing Shale Member in the Wolfcamp Series. *Waagenoconcha* is one of the Permian elements that determined this placement.

### Genus *Waagenoconcha* Chao, 1927

*Waagenoconcha* Chao 1927:24, 85.—Dunbar and Condra, 1932:190.—R. E. King, 1931:80.—Muir-Wood and Cooper, 1960:252.—Williams et al., 1965:H488.—Grant, 1966a:660, 1966b:1063.

*Ruthenia* Fredericks, 1928:789.

Although this name has been in use for a long time it is not distinctly understood. The internal characters definitely relate the genus to *Echinoconchus* and its allies. The generic characters related by Chao (1927) are based on the exterior, especially the spine arrangement "quincuncially arranged tubercular spines in the youthful and adult stages, which become smaller and closely packed together in old age." North American species, such as *Productus nevadensis* Meek, which do not strictly con-



form to this definition, have been put into *Waagenoconcha*. Lately these have been separated as a separate genus by Muir-Wood and Cooper (see 1960:244, *Bathymyonia*).

TYPE-SPECIES.—*Productus humboldti* d'Orbigny (1842:54, pl. 5: figs. 4–7); see also Kozłowski (1914: 40, pl. 7: figs. 7–9, text-fig. 9)

DIAGNOSIS.—Productacea having quincuncially arranged hairlike spines on body of shell abruptly decreasing in size at the anterior to form a band around the margin of closely packed small spines.

COMPARISON.—*Waagenoconcha* appears to be closest to *Bathymyonia* among known genera. External differences of importance are apparent, however. In *Waagenoconcha*, as shown by specimens of *W. humboldti* from Bolivia, the posterior half or more of the shell or essentially the visceral disc region is covered by elongated spine bases, arranged in quincunx, from which halteroid spines arise at a low angle to the shell surface. In the anterior half or on the trail slope the spines become abruptly of much smaller size and are more crowded to form a dense mat of extremely delicate spines that point upward rather than toward the substrate. Several species such as *W. irginae* (Stuckenberg) and *W. abichi* (Waagen) show this feature well, but all are relatively small forms. This feature is somewhat less clearly shown by the gigantic forms in the two upper Word Formation limestone members.

*Bathymyonia* has an entirely different development of the spines. The posterior part of the shell is characterized by elongated spine bases bearing long thin spines as in *Waagenoconcha*, but the anterior half or more of the shell is distinctly lamellose and the spines appear in bands; no diminution in size of all the anterior spines can be detected. In some specimens more delicate spines than those in the posterior half appear among the trail spines on the lamellae, but abundant, larger spines are still present. The anterior lamellae give *Bathymyonia* the exterior appearance of *Echinoconchus* or *Echinaria*, and it is to the former genus that Muir-Wood and Cooper (1960:244) compared the genus. The external similarity of *Bathymyonia* to *Echinoconchus* is still more striking when one adds to the similarity of the spine arrangement the generally parallel sides and elongate-rectangular outline. This echinoconchid external habit is another good distinction from *Waagenoconcha*.

Internal differences between the two genera are

not clear. Generally the cardinal process, median ridge, and muscle scars of *Bathymyonia* are much more strongly developed. In fact, the genus takes its name from the deep insertion of the muscles of the pedicle valve in the type specimen. No specimens of *Waagenoconcha* so strongly thickened have been found in the United States. *Waagenoconcha* from the Glass Mountains is definitely a fragile and delicate shell, regardless of size.

The distinction between *Waagenoconcha* and *Bathymyonia* is, therefore, based almost entirely on external details in *Bathymyonia*: the uniformity of size of the spines of both valves, the development of lamellae anterior to the visceral disc region, and the strongly convex but longitudinally rectangular outline. Internal features are similar but those of *Bathymyonia* are more strongly developed.

DISCUSSION.—*Waagenoconcha* is rare in the Glass Mountains, where it is encountered mostly in the Cathedral Mountain and Road Canyon formations and in the limestone members of the Word Formation. In the upper Gaptank Formation and Wolfcampian rocks it is extremely rare, although it might be found anywhere in these formations. The U. S. National Museum of Natural History collection contains some interesting specimens of the genus from all these levels, but good specimens are few.

### *Waagenoconcha convexa*, new species

PLATE 356: FIGURES 1–6; PLATE 357: FIGURES 1–43

*Waagenoconcha montpelierensis* Muir-Wood and Cooper (not Girty), 1960:407, pl. 90: figs. 1–2 [not figs. 3–9 (= *W. magnifica*, new species)].

Medium size for genus, midwidth slightly greater than length; hinge narrower than midwidth; cardinal extremities obtusely rounded; sides regularly rounded and anterior margin slightly rounded to nearly straight. Profile with brachial valve gently concave, but pedicle valve strongly convex. Surface of both valves completely spinose and consisting of crowded mat of fine rounded spine bases bearing hairlike spines diminishing in size anteriorly. Spines arising at low angle to surface.

Pedicle valve with fairly strong convexity in lateral profile, convexity fairly uniform to umbonal region, there narrowly curved, anterior profile high domed, with steeply sloping sides and deeply indented top. Beak strongly incurved, umbo narrowly swollen and steep-sided. Median region swollen.

Sulcus originating on umbo, moderately deep, rounded, and extending to anterior margin. Flanks bounding sulcus moderately swollen and rounded. Ears slightly flattened, not prominent.

Brachial valve gently concave, anterior deflected gently dorsally; umbonal region depressed; fold prominent but low and subcarinate, appearing just anterior to umbonal depression and extending to anterior margin; flanks bounding fold forming most concave part. Ears not differentiated.

Pedicle valve interior with longitudinally striated and elongated diductor scars; adductor scars not elevated on platform. Hinge region strongly granulose.

Brachial valve interior with long, narrow, and long-shafted cardinal process having small trilobed myophore; cardinal process buttress and brevisseptum united to form single median septum. Adductor scars not thickened, forming oval patch, strongly dendritic. Lateral ridges strong. Anterior slope with closely scattered and thick endospines.

#### MEASUREMENTS (in mm).

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702c							
149653a	28.3	24.0	41.0?	21.0?	31.8	11.1	10.0
149653b	26.9	21.3	43.0	21.8	29.0	12.8	10.7
149653c	23.0	18.2	39.0	15.8	25.0	11.6	9.6
149653d	22.7	18.0	37.5	17.6	24.3	11.2	9.0
149653e	19.6	16.4	28.5	14.3	20.8	8.2	5.8
149653f	16.0	12.6	25.0	14.0?	18.3	7.3	5.9
149653g	13.4	11.4	19.0	10.2	16.2	5.6	4.7
149653h	11.6	10.2	17.5	7.5	12.8	5.4	4.2
149653i	10.8	9.4	16.0	7.0	12.0	4.7	4.1
149653j	8.7	8.0	13.0	6.5	10.0	3.6	3.2
149653k	7.7	7.0	11.5	4.5?	8.7	2.9	2.2
149653l	7.0	6.2	9.5	5.0	7.0	2.8	2.1
149652	22.5	18.3	36.0	17.8	24.3	10.0	9.2
(holotype)							

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain and Road Canyon formations.

LOCALITIES.—Cathedral Mountain: USNM 712o, 721u, 730q. Road Canyon: AMNH 503; USNM 702c, 703, 703a, 703c, 703d, 707e, 720d, 720j, 721r, 721s, 721x, 722e, 724b, 724j 726d, 732j.

DIAGNOSIS.—Medium-sized, subcircular *Waagenoconcha* with fine, round spine bases.

TYPES.—Holotype: USNM 149652. Figured paratypes: USNM 124154; 149653c, d, i, l-n; 154028; 154029a; 154031a-c; 154032a, b. Measured paratypes: USNM 149653a-l. Unfigured paratypes: USNM 149653a, b, e-h, j, k.

COMPARISONS.—This species is the smallest of the named species of *Waagenoconcha* from the Glass Mountains. It is readily distinguished from *W. prophetica*, new species, by the different size and proportions, that species not being so circular in outline as *W. convexa*. Furthermore, the very strong differentiation in size of spine bases between the anterior halves of *W. prophetica* is not so markedly

developed in *W. convexa*. The spine bases and spines of the Leonardian species are much finer than those of the Wolfcampian form.

*Waagenoconcha magnifica*, new species, is so much larger that little confusion between the two species is likely. The young of *W. magnifica* which also have a strongly arched pedicle valve may be confused with the young of the Leonardian species. The shape of the two is similar, and both have a strong sulcus on the pedicle valve, but the spine bases and spines of *W. convexa* are much finer and more delicate than those of *W. magnifica*.

DISCUSSION.—This species is common only at USNM 702c, but there, compared to the abundance of other species, it is actually a minor constituent. Furthermore, it is doubtful that the largest specimen recorded there really represents the maximum size attained by the species. One large pedicle valve from USNM 721u has a length of about 32 mm and width of 43 mm, dimensions larger than those of the largest measured specimen above. Probably this

is about maximum for the species, but this large specimen is wider than usual. Its fellows from the same locality are nearly circular, the specimen nearest in size measuring 28 mm long by 30 mm wide.

Perhaps the most notable feature of this species is the extremely hairlike quality of the spines preserved in a number of specimens. These are densely arranged over the surface and arise at a very low angle to the shell surface, thus making a dense cover over the exterior. The true length of the spines has not been seen, but they were probably long, especially on the cardinal extremities.

The brachial valve exhibits variation in the exterior as well as the interior. Young specimens are nearly flat, and the youngest have scarcely any concavity. The larger specimens, on the other hand, vary from almost flat to fairly strongly concave. Other than the variation in convexity, no other differences could be detected.

This species has strong lateral ridges, and this character appears in the young as well as the older specimens. In the youngest specimens the median ridge or septum is not well developed. The buttressing septum appears just anterior to the cardinal process in the youngest specimens (about 10 mm long) but extends for only about one-third valve length. It is continued as a low, indistinct, slightly elevated ridge anteriorly. No clear separation into buttress and brevisseptum can be discerned, as in *Juresania* Fredericks and some other genera. In specimens of 15 mm length, the septum extends without interruption from the cardinal process to the anterior side of the visceral disc.

The brachial valve of this species is a thin and delicate shell, yet the endospines that surround the visceral region are coarse and stout, and in some instances fairly long. They are a conspicuous feature of the interior.

### *Waagenoconcha leonardensis* R. E. King

*Waagenoconcha leonardensis* R. E. King, 1931:80, pl. 19: figs. 3a, 3b [only].

This species is represented by three specimens. One paratype (R. E. King, 1931, pl. 19: figs. 2a, 2b) belongs to *Kochiproductus* and is tentatively placed with *K. elongatus*, new species. The second paratype is clearly a species of *Rhamnaria* and is placed in *R. grandis* Cooper and Grant, new spe-

cies. The holotype is only a half specimen; it has the spine ornament of *Waagenoconcha* but there is not enough of it to identify our silicified material with it. King's specimen is from the lower part of the Cathedral Mountain Formation (R. E. King locality 120) and might be related to our *W. convexa*, but it is not possible to be sure.

### *Waagenoconcha magnifica*, new species

PLATE 354: FIGURES 1-15; PLATE 355: FIGURES 18-24; PLATE 356: FIGURES 7-16

*Waagenoconcha montpelierensis* R. E. King (not Girty), 1931:81 pl. 19: figs. 5, 6.—Muir-Wood and Cooper, 1960: 254, pl. 90: figs. 3-9.

Large for genus, wider than long, greatest width along hinge in adults; cardinal extremities rounded, forming slightly flattened ears; sides rounded and sloping medially in adults; anterior margin broadly rounded; brachial valve nearly flat to gently concave. Surface of both valves marked by mat of fine elongated spine bases giving rise to fine hair-like spines at low angle to shell surface; spine bases measuring about five per 5 mm on venter and about seven per 5 mm on anterior margin.

Pedicle valve strongly and evenly convex in lateral profile, except for narrowly curved umbonal region. Anterior profile high domed, with steeply sloping sides and gently indented median region. Umbonal region narrowly swollen and extended only short distance beyond hinge, when seen in dorsal view. Median region swollen, trail slightly flattened. Sulcus shallow and narrow, originating on umbo and extending to anterior margin as impressed groove. Flanks bounding sulcus moderately swollen.

Brachial valve nearly flat to gently concave; umbonal region broad and shallowly depressed; ears flattened but not strongly differentiated; fold strongest at midvalve, originating just anterior to the umbonal depression and extending to front margin, there broad and almost obsolete. Sides and anterior gently deflected dorsally.

Pedicle valve interior with muscle scars lightly impressed; adductor scars on low ridge formed by exterior sulcus but not thickened to form platform. Lateral regions and those anterior to muscle field marked by strong pustules or endospines.

Brachial valve with long-shafted cardinal process

with trilobed myophore directed dorsally; cardinal process buttressed by slender but strong rounded median ridge becoming slender septum anteriorly and extending two-thirds valve length from hinge.

Lateral ridges short, slender; hinge margin deeply but minutely pitted. Visceral region surrounded by area of thick and long endospines. Adductor scars dendritic but only slightly thickened.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706e							
149676a	54.6	45.0?	88.0	62.4	59.4	25.0?	?
(holotype)							
149676b	?	46.4	?	70.4	57.0	?	?
149676c	39.8	31.5?	?	48.0	44.8	15.0	?
149676d	33.5	27.8	51.0	34.6	35.2	15.3	12.4
149676e	10.1	?	16.0	8.2	12.3	4.5	?
124153a	?	28.2	?	38.0	40.8	?	?
124153b	?	44.9	?	62.8	64.6	?	?
USNM 706b							
149673	21.5	18.4	32.0	18.2	26.0	14.2	7.4

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank, Willis Ranch, Appel Ranch members and lens between the last two), Cherry Canyon Formation (Getaway Member).

LOCALITIES.—China Tank: USNM 706c, 726r, 733q. Willis Ranch: AMNH 505; USNM 706, 706e, 723t. Appel Ranch: 704, 706d, 715i, 719z, 722t, 727j. Lens: 706b. Getaway AMNH 512; USNM 728, 732.

DIAGNOSIS.—Large, wide-hinged *Waagenoconcha* with median fold most prominent at midvalve.

TYPES.—Holotype: USNM 149676a. Figured paratypes: USNM 124153a–c; 149676b–e; 154030a, b. Measured paratypes: USNM 124153a, b; 149673; 149676 b–e; 149677c. Unfigured paratypes: USNM 149673, 149677.

COMPARISONS.—This species in adult form is easily recognized in the Glass Mountains because no other approaches it in size. Its transverse form distinguishes it from the common Arctic species of large size, such as *W. payeri* (Toula). Differentiation of the young of this species from others of about the same size is another matter. In the Glass Mountains, the young of *W. magnifica* are deeply sulcate and comparatively more strongly ornamented. The spine bases are stronger and the spines coarser than those of *W. prophetica* or of *W. convexa*, both new species, and somewhat more distantly placed.

DISCUSSION.—This is a rare species, especially in the adult form. Large specimens are occasionally

located on the dip slopes of the Word Formation limestones members on the south side of Hess Canyon northeast of Hess Ranch, but they are generally so damaged by weathering or so crushed as to be useless for study. When seen with its full complement of halteroid spines, the surface suggests that of an irregular sea-urchin. The full length of the spines has not been seen, either in etched specimens or on the outcrop, but they must have been fairly long.

The largest of the pedicle valves are remarkable for the extremely thin and fragile shell. Consequently, few marks of the muscles or other fleshy parts are well impressed. The external sulcus is usually fairly deep and is recorded on the interior as a moderately strong median ridge, especially at midvalve. This served as an attachment for the adductor scars, but no thickening to form a platform has been seen in the largest of the specimens.

This species does not have strongly developed lateral ridges at any of the stages available for study. The smallest brachial valve, which is 8.5 mm long, has a well-developed median septum that is continuous throughout its length and forms a buttress to the cardinal process. A brevisseptum is thus not differentiated from the buttress. In the largest adult this continuous structure is never greatly thickened, either proximally or distally. It does taper from a rounded ridge proximally, to a slender blade-like septum at its distal end, which extends to the

anterior edge of the visceral disc, at least two-thirds the valve length. As in many other species the posterior margin is pitted to receive granules from the pedicle valve in what appears to be an articulating device. In *W. magnifica* the pits and granules are very fine.

At all observed stages of development the brachial valve presents its narrowly trilobed cardinal process to the dorsal side. It also remains narrow and slender into large adulthood. In the largest specimens some thickening at the base of the shaft takes place. An important feature of this species is the forest of endospines covering the long slopes anterior to the visceral disc. Individual spines are long and stout. The adductor field is scarcely thickened and the scars are lightly impressed.

As in *W. convexa*, variation in the concavity of the brachial valve is also evident in this species. The young are generally flat, but adults and old specimens are variable in this respect. The largest specimen is only gently concave, but an intermediate form is fairly strongly concave (USNM 124153b). Several brachial valves from USNM 706 are slightly geniculated a short distance anterior to midvalve. Specimens so bent commonly have a larger endospinose area surrounding the visceral disc, which is narrowed or restricted by the geniculation. Other details of a specific character are not altered, however, and it has been impossible, with the material at hand, to make a specific separation on the more concave shells.

Several specimens from USNM 715i are referred to *W. magnifica*, but none of the specimens is over 35 mm wide, thus representing young adults, if they are indeed the same species. No fragments indicating specimens of larger size commensurate with adults of *W. magnifica* have been found. The proportions of these specimens are in accordance with those from USNM 706e, from which the type specimen was taken.

### "*Waagenoconcha montpelierensis*" (Girty)

*Productus montpelierensis* Girty, 1910:30, pl. 2: figs. 5, 6.—  
Muir-Wood and Cooper, 1960:254 [not pl. 90: figs. 1–9  
(= *W. convexa* and *W. magnifica*, both new)].

This species has been widely identified in the United States as a variety of waagenoconchas. The specimen figured by R. E. King (1931:81, pl. 19: figs. 5, 6) is shown above to be *W. magnifica*, new

species. The specimens from Mexico figured by Cooper (1953: 42, pl. 13: figs. 6–14) do not belong to this species, although the specimens in figures 1–5 of plate 13 appear to be a genuine *Waagenoconcha*. The difficulties in identification arise from an interpretation of the exterior.

Girty's type specimen of *W. montpelierensis* is small, having a length of 22 mm and a width at midvalve of 26.5 mm. It is fairly thin but suggests species such as *W. irginae* (Stuckenberg) or *W. prophetica*, new species, except that the spine bases are of uniform size over the entire shell. Thus Girty's species, as exhibited by the holotype and paratype, is unlike other named species described herein. Girty's specimens do suggest the young of a larger species of *Waagenoconcha*, or of *Bathymyonia nevadensis* (Meek), the latter being abundant at this level in the Permian and in the northwestern part of the United States. Young specimens of *B. nevadensis* are identical to Girty's *P. montpelierensis* and attain a length of slightly more than 30 mm before forming the lamellose anterior characteristic of *Bathymyonia*. It is our belief, therefore, that *W. montpelierensis* should be added to the synonymy of *Bathymyonia nevadensis*.

In discussing *W. montpelierensis* from Sonora, Mexico, Cooper (1953:43) suggested that *W. montpelierensis* should be "more broadly viewed than hitherto" and pointed out that small forms similar to Girty's type were the young of larger ones. The latter prove to be *Bathymyonia*, and part of Cooper's *W. montpelierensis* should also be added to the synonymy of *B. nevadensis*. The specimens from Mexico illustrated by Cooper (1953, pl. 13: figs. 1–5) show the characteristic abrupt change in size of spine bases on the trail slope and are regarded as a genuine species of *Waagenoconcha*, although unnamed at present.

### *Waagenoconcha platys*, new species

PLATE 355: FIGURES 1–11

Medium size for genus, roundly elliptical in outline, greatest width at midvalve; cardinal extremities strongly rounded; nearly plano-convex. Sides strongly rounded; anterior margin broadly rounded. Surface covered by mat of hairlike spines having fine, elongate bases, about two per mm on venter.

Pedicle valve gently and unevenly convex in lateral profile, curvature increasing posteriorly to nar-



rowly curved umbonal region. Anterior profile broad, narrow-topped dome with long moderately steeply sloping sides. Umbonal region short, narrowly swollen, and protruding slightly posterior to hinge. Sulcus originating anterior to umbo on venter, narrow and shallow, but extending to anterior margin. Flanks bounding sulcus gently swollen but with long lateral slopes. Ears not developed.

Brachial valve nearly flat but with umbonal region forming depression broadening anteriorly and divided into two parts by low median fold originating just anterior to umbonal depression. Fold low and gently rounded, indistinct at anterior margin. Depressed region bounded laterally by oblique folds from beak setting off flattened area on cardinal extremities.

Pedicle valve interior unknown.

Brachial valve interior with small cardinal process usually narrow and fairly short to fit under low umbo of pedicle valve; median septum low and slender; adductor scars scarcely visible.

MEASUREMENTS (in mm).—From locality USNM 702c, specimen USNM 149647 (holotype): length 22.8, brachial valve length 20.8, surface length 29.0, hinge width 14.8, midwidth 30.0, height 6.9, thickness 6.2.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 702c, 707e, 710z, 724a, 735a.

DIAGNOSIS.—Roundly elliptical, flattened *Waagenoconcha* with fine ornament.

TYPES.—Holotype: USNM 149647. Figured paratypes: USNM 154027a, b.

COMPARISONS.—This species differs from all other described in its extremely flattened form, nearly flat brachial valve, and absence of ears.

DISCUSSION.—The exterior form and profile of this species is unique. It is flat, has extremely fine

spine bases, and the cardinal extremities are strongly rounded. The brachial valves, of which we have a fair number, are almost flat and have a small cardinal process to fit under the very small umbonal region.

*Waagenoconcha prophetica*, new species

PLATE 352: FIGURES 20–23; PLATE 355: FIGURES 12–17

Fairly large, subquadrate in outline, length less than midwidth; sides gently rounded; anterolateral extremities narrowly rounded; anterior margin broadly rounded. Hinge less than midwidth. Surface unevenly spinose, posterior half marked by elongate spine bases shaped like needle points with hair-like spine extending from distal side of each point; anterior quarter abruptly marked by spine bases gradually decreasing in size anteriorly and becoming less elongated and being minute at margin, each base giving rise to delicate spines; brachial valve similarly marked, but with small pits in addition to spine bases.

Pedicle valve unevenly convex in lateral profile, posterior half somewhat flattened, next quarter somewhat narrowly rounded, and anterior quarter gently convex. Anterior profile forming flat-topped dome with steeply sloping sides and slightly depressed middle. Sulcus originating on umbo, narrow and shallow, becoming indistinct at anterior margin. Umbonal region narrowly swollen and median region moderately inflated. Flanks moderately rounded.

Brachial valve flattened but marked medially by low median ridge spreading anteriorly and becoming indistinct at margin; valve geniculated, anterior margin bent moderately toward pedicle valve; umbonal region depressed, ears not differentiated.

Interior of both valves not known.

MEASUREMENTS (in mm).—*Waagenoconcha prophetica*, new species:

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 511r							
124073	31.0	27.7	45.0	?	34.2	14.8	11.2
149670	29.0	24.5	45.0	29.2	34.6	15.0	11.0
(holotype)							
USNM 701v							
149669a	36.0	?	56.5	35.3	41.9	20.0?	?
USNM 701q							
149668a	?	36.3	?	39.4	45.3	?	?

STRATIGRAPHIC OCCURRENCE.—Finis and Jacksboro members of Graham Formation in the Cisco group, Gaptank Formation (*Uddenites*-bearing Shale Member), Neal Ranch Formation.

LOCALITIES.—Finis-Jacksboro: USNM 511r = Renfro locality 45. *Uddenites*: USNM 701e, 701q, 701v. Neal Ranch: 701.

DIAGNOSIS.—*Waagenoconcha* with moderately coarse spine-bases in posterior half and the maximum convexity about three-quarters the length from the beak.

TYPES.—Holotype: USNM 149670. Figured paratypes: USNM 149668a, 149669. Measured paratypes: USNM 124073, 149668a, 149669a. Unfigured paratype: USNM 149668b.

COMPARISONS.—This species is most suggestive of the type species of the genus, *W. humboldti* (d'Orbigny), and of *W. irginae* (Stuckenberg) in its general form and ornamentation. It differs from the latter in being larger, in having the posterior marked by larger spine bases, in having a less regular profile than the Russian species, and in having a less well-defined median fold.

*Waagenoconcha prophetica* is also much larger than *W. humboldti* and differs markedly from it in ornament and profile. The Texas species is not as strongly sulcate as the South American one, and the anterior border of spines and their bases of diminishing size is broader than that of *W. prophetica*. The spine bases of the Bolivian species appear to be more crowded than those of the Texas specimens.

DISCUSSION.—The description of this species is based largely on specimens from the Finis and Jacksboro members of the Graham Formation near Jacksboro, Texas, which preserve the exterior details almost to perfection. The larger specimens from the *Uddenites*-bearing Shale Member referred to this species agree in most details but the identification is not certain. It is not possible on these specimens to see the spine bases in detail, and some uncertainty exists as to the exact place on the surface where the spines begin to decrease in size. The measurements possible on these specimens indicate that the Jacksboro examples undoubtedly resembled the young of these from the *Uddenites*-bearing Shale Member.

These specimens are the second report of this genus in the *Uddenites*-bearing Shale Member and the first report of it in the Midcontinent region of north-central Texas. R. E. King (1931:81) records

it in the form of *W. montpelierensis* (Girty) from his locality T88 which is the *Uddenites*-bearing Shale Member at Wolf Camp.

The genus was found rarely higher in the Neal Ranch Formation but it may be expected from the Lenox Hills Formation as well. A specimen of *Waagenoconcha* having the profile and size of *W. irginae* was taken from the Hueco limestone just above the Powwow conglomerate in Powwow Canyon east of El Paso and is described below. It is probable that *Waagenoconcha* will be found at many levels when the Permian rocks receive yet more careful collecting.

### *Waagenoconcha sulcata*, new species

PLATE 357: FIGURES 44-48

Medium size for genus, subcircular outline, length and width nearly equal; sides and anterior rounded; plano-convex in lateral profile; umbonal region low and beak small; pedicle valve strongly convex and deeply sulcate, sulcus originating near beak and extending to anterior margin; flanks bounding sulcus narrowly swollen. Brachial valve flatly concave, geniculated gently ventrad about four-fifths of distance from posterior margin; umbonal region shallowly depressed; fold low, subcarinate, not conspicuous, arising just anterior to umbonal depression. Ears slightly deflected and demarcated by low, oblique ridge. Spine bases crowded, large in visceral disc area but much diminished in size on trail.

MEASUREMENTS (in mm).—From locality USNM 725z, specimen 154033 (holotype): length 26.9, brachial valve length 21.7, surface length 45.0, mid-width 28.6, hinge width 21.0, height 12.5, thickness 11.2.

STRATIGRAPHIC OCCURRENCE.—Hueco Canyon Formation (base).

LOCALITY.—USNM 725z.

DIAGNOSIS.—Deeply sulcate *Waagenoconcha*.

TYPES.—Holotype: USNM 154033. Unfigured paratype: USNM 155034.

COMPARISON.—This species is more deeply sulcate and has a thicker body for its size than any Glass Mountains species. It resembles *W. irginae* (Stuckenberg) and *W. humboldti* (d'Orbigny) but is much more deeply sulcate than either of them.

DISCUSSION.—This is a very rare species in the Hueco Group.

## Family BUXTONIIDAE Muir-Wood and Cooper, 1960

Productacea having long, dorsally recurved trilobate cardinal process with supporting buttress plates in youth, or buttress plates fusing with septum leaving antron at posterior end of septum; costate or lamellose and spinose ornament on each valve, with anterior spinose bands or rims.

### Subfamily BUXTONIINAE Muir-Wood and Cooper, 1960

Buxtoniidae having an antron in posterior end of septum, except in older growth stages; ornament rugose, costate, and spinose in each valve, with anterior spinose bands or rims.

Genera in West Texas: *Kochiproductus* Dunbar, 1955; and *Ametoria*, new genus.

*Kochiproductus* is frequently found in fragmentary form. The shell is often large for a brachiopod and therefore susceptible to breakage before fossilization. Its large size also makes recovery from acid residues difficult. The genus is commonest in Wolfcampian to Cathedral Mountain rocks. *Ametoria* is only known from the Road Canyon Formation. Guadalupian rocks of West Texas have not yielded the genus, so far as we know.

### Genus *Kochiproductus* Dunbar, 1955

*Kochiproductus* Dunbar, 1955:107.—Muir-Wood and Cooper, 1960:259.—Williams et al., 1965:H490.

These are completely costate Buxtoniidae having a brush of halteroid spines on the ears; the posterior or visceral disc region of both valves reticulated, regularly on the brachial valve but raggedly on the pedicle valve. The genus makes up a group of usually large to gigantic productids that are fairly widespread in the Permian and are especially common in Arctic regions.

TYPE-SPECIES.—*Productus porrectus* Kutorga (1844:96, pl. 10; fig. 3).

DISCUSSION.—This genus is not yet completely understood because it is rare or unusual at most places. In the 48 contiguous United States it is common only at a few localities and is seldom well-preserved. Species described in this country that belong in this genus are *Productus peruvianus* d'Orbigny, *P. longus* Meek, and *Buxtonia victoricensis* R. E. King.

## *Kochiproductus elongatus*, new species

PLATE 358: FIGURES 4–6; PLATE 360: FIGURE 3?; PLATE 361: FIGURES 9–11?

*Waagenoconcha leonardensis* King (part), 1931:80, pl. 19: figs. 2a,b [not figs. 3 and 4].

Large, elongate-oval in outline with gently rounded sides and broadly rounded anterior margin. Hinge narrower than midwidth; ears small and inconspicuous, approximating right angle. Surface consisting of rows of numerous elongate spine bases with crests facing anteriorly and bearing delicate spines; pedicle valve without conspicuous concentric wrinkles; rows of spine bases alternating longitudinally in opposite rows, spine bases of one row being opposed laterally by gaps in adjacent rows. Brachial valve with interrupted concentric undulations or pits corresponding to spine bases of opposite valve; brachial valve spines hairlike, arising vertically from interrupted undulations. Spines on flanks concentrated into bands; ears of pedicle valve with dense brush of fine spines.

Pedicle valve in lateral profile having fairly moderate curve except in umbonal region, there abruptly and narrowly curved. Anterior profile broad convex dome with nearly vertical sides and deep median furrow. Beak small and strongly incurved; umbo narrowly swollen and protruding conspicuously posterior to hinge, seen in dorsal view. Median region strongly swollen. Sulcus originating on umbo, narrow and moderately deep, widening and deepening anteriorly to front margin, there conspicuous. Flanks bounding sulcus narrowly rounded and swollen.

Brachial valve forming broad shallow concavity; umbonal region flattened; fold originating on anterior side of umbonal region, rising gently anteriorly, broadly carinate and low. Areas bounding fold shallowly concave, being most concave parts of valve. Sides short and steep; anterior not greatly elevated.

Interior details of specimens probably belonging to this species are illustrated on plate 361.

MEASUREMENTS (in mm).—From locality USNM 710r, specimen 152732 (holotype): length 70.6, brachial valve length 56.0?, surface length 112.0, hinge width 39.0\* midwidth 56.4, height 35.0?, thickness 29.2?.

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch and Bone Spring formations.

LOCALITIES.—Skinner Ranch: (?) R. E. King T6; USNM 710r. Bone Spring: AMNH 624.

DIAGNOSIS.—Large *Kochiproductus* with narrow hinge and coarse spine bases.

TYPES.—Holotype: USNM 152732. Figured specimens: T10345, USNM 153903a, b.

COMPARISON AND DISCUSSION.—This species is characterized by its elongate and narrow form and the narrowness of the hinge. In these respects it differs strongly from other species described herein, all of which have wide hinges and expand somewhat anteriorly. The Arctic species from Greenland described by Dunbar (1955) are transverse forms and not shaped like the Glass Mountains species. This is also unlike *K. freboldi* (Stepanov), which is squarish, and *K. transversus* Cooper and *K. porrectus* (Kutorga), which are strongly transverse.

*Kochiproductus elongatus* is also unusual in the poor development of reticulation of the ornament in the umbonal and visceral disc regions of both valves. This is usually well developed in the genus. In this respect *K. elongatus* resembles *Bathymyonia nevadensis* (Meek) but is much larger and does not have well-defined bands on the anterior part of the shell.

The specimen figured by R. E. King and recorded in the synonymy above may be a young specimen of *K. elongatus*.

### *Kochiproductus occidentalis* (R. E. King)

PLATE 358: FIGURES 1–3

*Buxtonia occidentalis* R. E. King, 1931:79, pl. 17: figs. 20, 21.

This species is poorly known, being represented in the collection of R. E. King only by fragments. Study of the type specimens is not much help in understanding the species. King figured two specimens, a large one and a smaller one, designated as cotypes in the explanation of Plate 17, figures 20 and 21. The larger specimen has the catalog number YPM 11528 given in the legend to King's plate 17, but the specimen bears the number YPM 11548. Although the specimen is crushed, the pedicle valve can be lifted from the brachial valve and information on the exterior of the more youthful parts of the specimen is thus obtained. The specimen is 36 mm long by 43 mm wide, but is incomplete in both directions. The pedicle valve is broadly sulcate, with moderately rounded flanks bounding the sul-

cus. The ornament consists of long spine bases highest anteriorly where the spine was sent off at a low angle. The brachial valve has a small, smooth, and swollen umbo but the remainder of the valve is intricately pitted. The myophore of the cardinal process is visible but is distally damaged. The visible part is bilobed and the myophore face is approximately parallel to the valve surface. The specimen is from King locality 93, from beds 9–12 of the Neal Ranch Formation.

The smaller specimen (YPM 11552) is a fragment of a pedicle valve showing a strongly incurved beak, broadly shallow sulcus originating on the umbonal region, and somewhat narrowly rounded flanks. The only ornament visible consists of elongated spine bases. The specimen is 19 mm long by 28 mm wide (based on half measure).

Although King (1931:80) states that specimens from King locality 75 are types, the two figured specimens which are not from this locality are stated to be cotypes. A holotype must be selected from these latter specimens, which are presumably the best ones or they would not have been figured. We select the larger of the two cotypes (YPM 11528) as lectotype for the species.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (beds 9 and 12 of P. B. King).

LOCALITIES.—R. E. King 91a, 93.

TYPES.—Lectotype: YPM 11548 (=11528). Paratype: YPM 11552.

DISCUSSION.—We have not identified this species with certainty in our collections. It is possible that our *K. primitivus* belongs here because small crushed individuals might be so identified. In the absence of any certain specific characters in the type specimen of *K. occidentalis*, the species must be left in uncertainty.

### *Kochiproductus primitivus*, new species

PLATE 361: FIGURES 12–14

Medium size for genus, longitudinally oval to subquadrate in outline; hinge about equal to mid-width; ears probably large, not preserved on any specimen. Sides nearly straight; anterior margin broadly rounded; anterior commissure uniplicate. Visceral disc region subreticulate, reticulation of brachial valve stronger and more clearly defined; concentric undulations strong on posterior margin

and base of lateral slopes. Costae numerous, slender, with interspaces nearly same width; costae marked by numerous spine bases, those of pedicle valve low and elongate, rising anteriorly to give off short, slender, curved spine. Spines of brachial valve slender, with rounded bases, at right angles to valve surface.

Pedicle valve forming fairly even, moderately strong curve in lateral profile, but umbonal region narrowly rounded; anterior profile broad low dome, steep-sided but with broad swale medially. Beak narrow and incurved; umbonal region strongly swollen but protruding posterior to hinge only short distance. Ginglymus small. Median region broadly swollen; sulcus originating on visceral disc, broad and shallow, deepening anteriorly to front margin, there conspicuous. Flanks bounding sulcus anteriorly narrowly rounded and prominent.

Brachial valve broadly concave, maximum depth near midvalve; umbonal region broadly concave; ears not strongly demarcated; sides moderately steep but anterior margin less so. Sulcus originating near midvalve, narrowly convex but with gently sloping sides.

Pedicle valve interior not known. Brachial valve interior with large, long-shafted cardinal process supported by widespread, strong buttress plates. Brevisseptum arising between buttress plates, slender and reaching to midvalve. Lateral ridges strong. Muscle field small, strongly dendritic.

MEASUREMENTS (in mm).—Hinge width unmeasurable.

		brach- ial valve length	sur- face length	mid- width	height	thick- ness
USNM 701e						
148947a	57.0	47.8	95.0?	57.8	27.0?	16.4+
USNM 702q						
148950 (holotype)	61.0	46.8	97.0	52.5	26.6	18.1+

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member).

LOCALITIES.—Gaptank: USNM 700g, 715z. *Uddenites*: USNM 701e, 701v, 701x, 702n, 702q, 704r, 721m.

DIAGNOSIS.—Medium size, narrow-hinged *Kochi-productus* with narrowly swollen umbonal region.

TYPES.—Holotype: USNM 148950. Figured

paratypes: USNM 148947a, 148951. Measured paratype: USNM 148947a.

COMPARISON.—Specimens of undoubted *Kochi-productus* from the Hueco Canyon Formation have long been identified as *K. peruvianus* (d'Orbigny). *Productus longus* Meek belongs to the same genus and is similar to the Hueco Canyon species. The latter, however, is so poorly preserved and crushed as to prevent good comparison. *Buxtonia victorioensis* R. E. King is still a third species referable to the genus *Kochi-productus* occurring in the Permian of Texas.

*Kochi-productus primitivus* is unlike any of the above species because it is generally smaller and somewhat differently proportioned. It has a narrow hinge, whereas the hinge of *K. peruvianus* and *K. victorioensis* extends laterally into prominent ears. The hinge region of *K. longus* (Meek) is not known from available specimens. Another prominent difference between *K. primitivus* and the Hueco Canyon species is the narrowness of the umbonal region of the former, compared to that of *K. peruvianus*. This characteristic is expressed in the young as well as in adults.

DISCUSSION.—This species is difficult to find in the shaly beds of the *Uddenites*-bearing Shale Member and is seldom well preserved when found. Unfortunately, no unweathered specimens were uncovered in all of the collecting in these mountains. See discussion under *K. occidentalis* (R. E. King).

### *Kochi-productus quadratus*, new species

PLATE 359: FIGURES 1-8; PLATE 361: FIGURE 15; PLATE 362: FIGURES 29-33

*Buxtonia peruviana* R. E. King (not d'Orbigny), 1931:80, pl. 18: figs. 1-3.—Muir-Wood and Cooper, 1960:259, pl. 75: figs. 10-12, pl. 77: figs. 1-7.

Medium size for genus; squarish in outline, length and width nearly equal; sides nearly straight to slightly rounded; anterior margin broadly rounded; hinge equal to or slightly greater than midwidth; ears narrowly rounded, seldom preserved; pedicle valve strongly convex; brachial valve fairly deeply concave; body cavity deep. Surface unevenly costellate, costellae discontinuous and with elongated spine bases. Spines delicate, brush of thin spines on ears and scattered body spines on shell body and trail, full length not known. Posterior



third irregularly concentrically wrinkled, wrinkles cancellating costellae. Brachial valve with concentric lamellae finer and more distinct than those of opposite valve and occupying most of visceral disc area; fine pits numerous, probably representing spines of other valve; brachial valve spines delicate, short and curved, about 5 mm in length.

Pedicle valve very strongly convex in lateral profile, maximum convexity near midvalve; anterior profile flattened dome with narrowly rounded margin and precipitous slopes descending to somewhat flaring margin. Beak strongly incurved over hinge line; umbonal region protruding moderately posterior to hinge line in dorsal view; sulcus originating near beak, broad, shallow, and extending to anterior margin. Sides flaring into flattened rim along sides and anterior.

Brachial valve fairly deeply concave, most concavity forming trough anterior to place of geniculation at about four-fifths distance anterior to posterior margin; ears flattened but poorly demarcated. Umbonal region fairly deep depression about 10 mm long; fold broad and low, originating anterior to umbonal depression but disappearing at anterior. Flanks descending steeply to visceral region.

Pedicle valve interior with only slightly thickened muscle region. Brachial valve interior with strong buttress plates to cardinal process in young; adults with small, elongate, slitlike antron or with antron obsolete and cardinal process buttressed by long, thick ridge extending to midvalve; cardinal process with short shaft but with myophore facing posterodorsally. Myophore narrow, trilobed. Anterior slopes strongly endospinose with thick stubby endospines.

MEASUREMENT: (in mm).—From locality USNM 725z, specimens 124065a (holotype) and 153900d, respectively: length 67.8, 63.0; brachial valve length 55.0, 49.6; surface length 115.0, 119.0; midwidth 73.6, 68.7; hinge width 70.0?, 74.0\*; height 40.7, 40.0; thickness 24.3, 20.6.

STRATIGRAPHIC OCCURRENCE.—Hueco Canyon Formation.

LOCALITY.—USNM 725z.

DIAGNOSIS.—Large, nearly square *Kochiproductus* with flared lateral margins, inconspicuous fold, and delicate spines.

TYPES.—Holotype: USNM 124065a. Figured paratypes: USNM 124065b, d, i; 153900a–d; (124065 e–g figures in Muir-Wood and Cooper, 1960). Un-

figured paratypes: USNM 124065c, e–g; 153900e, f.

COMPARISON.—This species is most like *K. primitivus*, new species, and *K. peruvianus* (d'Orbigny), for which it has been mistaken. It differs from the former in having larger size, wider umbonal region, broader beak, and slightly stronger fold. The interior buttress plates of the cardinal process in adult brachial valves of *K. primitivus* are strongly developed on each side of the brevisseptum, which is not itself united with the buttress plates as in *K. quadratus*. The two species are similar and easily confused.

*Kochiproductus peruvianus*, when fully grown, attains a larger size than the West Texas species and is more strongly sulcate, but this is variable. The ornament is somewhat stronger on the Peruvian shell and the umbo projects farther posterior to the hinge than in the Texas species.

DISCUSSION.—*Kochiproductus quadratus* is best known at its topotype locality, where it is abundant. It is rare elsewhere and was not seen in the Lenox Hills Formation, which is a correlate of the Hueco Canyon Formation. Chronic (1949:88) states that this species is not known in the Permian of Peru and identifies it from the Middle Pennsylvanian (Tarma Group). The specimen figured by Chronic seems much wider than those from Bolivia. Chronic's specimens represent the earliest occurrence of the genus.

### *Kochiproductus victorioensis* (R. E. King)

PLATE 360: FIGURES 8–12

*Buxtonia victorioensis* King, 1931:80, pl. 19: fig. 1.

Holotype large but badly crushed, both valves present but dorsal valve covered by very siliceous limestone. Exact shape indeterminable, slightly wider than long and subquadrate in outline; sides gently rounded; anterior margin broadly rounded; beak strongly incurved; umbo moderately swollen; sulcus originating on the umbo and extending to the anterior margin, flanks moderately swollen and with steep sides. Hinge forming widest part; ears convex, triangular, narrowly rounded. Surface covered by costellae, four or five per 5 mm at front margin; visceral region semireticulate. Costellae irregularly swollen by spine bases, giving an interrupted appearance. Ears and posterior margin with

MEASUREMENTS (in mm).—From King locality 498, specimen YPM 11615 (holotype): length 53.4, brachial valve length 42.2, surface length 112.0?+, hinge width 73.0\*, midwidth 59.5?, thickness unmeasurable.

TYPES.—Holotype: YPM 11615.

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation (Victorio Peak Member).

LOCALITY.—R. E. King 498.

DIAGNOSIS.—Costellate *Kochiproductus* with large ears.

COMPARISON AND DISCUSSION.—This species differs from the Hueco Canyon *K. quadratus*, new species, in having much finer ribbing, a narrower umbonal region, and narrowly rounded ears.

In the Glass Mountains this species has not been definitely identified; a single poor specimen from the Skinner Ranch Formation (top) agrees in gross form but is somewhat more coarsely ribbed.

### *Kochiproductus* species 1

PLATE 358: FIGURES 7–9

Large, subquadrate outline, hinge equal to midwidth; sides gently rounded; anterior margin broadly rounded. Ears approximating right angle, small. Surface finely costate but with concentric undulations on posterior margin, ears, and base of lateral slopes, not well marked on venter. Body spines not seen; spine bases indicating thick cluster of ear spines.

Pedicle valve with unequally convex lateral profile, posterior half consisting of venter and umbonal region, strongly rounded but anterior half or trail gently convex. Anterior profile high, steep-sided dome. Umbonal region narrowly and strongly swollen; median region greatly swollen; sulcus originating on umbonal region, shallow and broad, becoming shallow and still broader anteriorly. Flanks bounding sulcus moderately rounded.

Brachial valve and interior unknown.

Figured specimen: USNM 152729.

MEASUREMENTS (in mm).—From locality USNM 707w, figured specimen 152729: length 62.8, surface length 133, hinge width 60\*, midwidth 65.5, height 42.0?, thickness unmeasurable.

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch Member).

LOCALITY.—USNM 707w.

COMPARISON AND DISCUSSION.—A single specimen of this large *Kochiproductus* is known and deserves special mention for its large size; it is one of the biggest productids in the Glass Mountains. It differs from other specimens of *Kochiproductus* in the strong enrollment of the pedicle valve, so that tangents to the trail and the umbonal region are approximately parallel. The specimen, in this feature, is unlike any other in the Glass Mountains. It might be the late adult stage of some small specimens but this could not be verified.

### *Kochiproductus* species 2

Large, shape uncertain, length 44 mm and width 58 mm based on half measure. Hinge narrower than maximum width; sides rounded but anterior margin not preserved. Lateral profile unequally convex, maximum curvature in umbonal region. Anterior profile broadly domed, top of dome broadly depressed. Sulcus wide and deep, originating on umbonal region. Flanks rounded.

Surface marked by numerous strong concentric wrinkles concentrated on lateral slopes, posterior margin, and ears. Costae narrow and elevated, interrupted by concentric wrinkles and small spine bases.

Described specimen: USNM 148960a.

STRATIGRAPHIC OCCURRENCE.—Lenox Hills Formation.

LOCALITY.—USNM 715.

COMPARISON AND DISCUSSION.—From the two specimens available it is not possible to be certain of the real characters of this species. It is unlike *K. primitivus*, new species, in having a broadly swollen umbonal region and a broad, deep sulcus. Furthermore, the undulations on the sides are stronger than those of *K. primitivus*. This species is very rare in the Lenox Hills Formation, but the strongly conglomeratic nature of the rock does not invite successful collecting.

### *Kochiproductus* species 3

PLATE 361: FIGURES 1, 2

Species represented by young, and fragments of immature and adult specimens. Full size unknown, outline of immature specimens elongate rectangu-

lar. Surface marked by strong interrupted costae and long elevated spine bases terminating in short to moderately long curved, suberect body, spines. Small ears with tuft of delicate halteroid spines.

Brachial valve with reticulated visceral disc and numerous slender spines. Brachial ridge strong, cardinal process long-shafted, with median depression and trilobed myophore. Median septum strong and rounded, expanding posteriorly to engulf buttress plates; antron forming deep pit. Young brachial valve with well-developed buttress plates surrounding distal end of brevisseptum.

Figured specimen: USNM 152730a.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation.

LOCALITIES.—USNM 701, 701c, 701d.

COMPARISON AND DISCUSSION.—The known specimens referred here are all fragments, but they indicate a fairly robust species with a narrowly swollen umbonal region and considerable size. Relationship to *K. primitivus* is suggested, but indeterminate. The coarseness of the umbonal region separates it from the Lenox Hills specimens.

#### *Kochiproductus* species 4

This is a large, finely costellate species with narrow hinge, having, in the broken condition, a length of 55 mm. The strong costellae make it unique among Glass Mountains species. It occurs in the Sullivan Peak Member of the Skinner Ranch Formation at USNM 710r.

Described specimen: USNM 148594.

#### *Kochiproductus* species 5

PLATE 361: FIGURES 3–8

Three specimens of an unusually shaped *Kochiproductus* were recovered from the residues at USNM 707d of the Sullivan Peak Member of the Skinner Ranch Formation. The best of the three pedicle valves has a surface length of 72 mm, and a length of 43.5 mm but the width is only 29.8 mm. The sulcus originates on the umbo, is shallow, and is uniformly narrow to about four-fifths the length, at which point it flattens considerably. Spine bases are elongated, scattered, and form short costellae. The flanks are rounded and steep-sided. One other fragment shows short spines at an angle of about

45°. No brachial valve was recovered, thus making generic assignment uncertain, but the ornament indicates *Kochiproductus*.

Figured specimens: USNM 152731; 153902a, b.

#### *Kochiproductus* species 6

PLATE 360: FIGURES 1, 2, 4–7; PLATE 361: FIGURES 16–19

Fragmentary material of a large species was found at several places. The specimens indicate a very distinctive species that ranges from the Cathedral Mountain formation into at least the lower part of the succeeding Road Canyon Formation. The species is somewhat reminiscent of *Peniculauris* and is of about the same size. Exterior details and dimensions are based on a crushed individual from USNM 703b and the details of the interior and spines on fragments from USNM 721u. The species is characterized as follows:

Large, subquadrate, length and width approximately equal; sides rounded; anterior margin indented medially; hinge narrower than midwidth in adults; ears large, acute to obtuse. Pedicle valve moderately convex, brachial valve slightly concave. Costellae narrowly rounded, interspaces wider than costellae. Visceral disc regions of both valves finely reticulated by concentric rugae. Spines numerous: many halteroid spines of delicate character on edges of ears, row of fine spines along posterior margin; body spines numerous, scattered, short, about 5 or 6 mm long, slightly curved and arising at angle of about 50°. Body spines often occurring at junction of rugae and costellae.

Pedicle valve moderately convex in lateral profile, greatest curvature in umbonal region; anterior profile broad dome with medial depression and short sloping sides. Umbonal region narrowly rounded, not protruding strongly beyond posterior margin; beak small and incurved. Sulcus originating on venter, moderately wide and extending to anterior margin; flanks moderately rounded.

Brachial valve in lateral profile nearly flat; median region marked by broad, carinate fold originating just anterior to umbo and widening toward anterior margin. Flanks bounding fold moderately concave; sides sloping moderately.

Pedicle valve interior with broadly flabellate diductor scars and an elongated adductor track. No ear baffles. Other details not visible.

Brachial valve interior with long and broad median depression extending from about 1/3 length from posterior margin to anterior. Depression occupied by low, bladelike brevisseptum uniting with narrow median buttress to cardinal process. Lateral ridges strong and elevated. Cardinal process long and narrow, with long shaft distally grooved on ventral face; myophore trilobed, narrow, with nearly parallel sides, and facing in dorsad direction. Adductor scars very narrow, long and slender. Most of interior surface with fine spines.

Figured specimens: USNM 152734a-c, 152735, 153901. Measured specimen: USNM 152733.

MEASUREMENTS (in mm).—From locality USNM 703b, specimen 152733: length 65.0\*, brachial valve length 54.2, surface length 75.0?, hinge width 65.0, midwidth 75.6\*, height?, thickness not determinable.

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain and Road Canyon formations.

LOCALITIES.—Cathedral Mountain: USNM 703b, 721u, 726o, 726y. Road Canyon: 721x.

DIAGNOSIS.—Large squarish *Kochiproductus* with broad carinate fold on the brachial valve and very long, narrow, slender cardinal process.

COMPARISON.—The flattish brachial valve with its broad carinate fold combined with the long, narrow cardinal process distinguish this species from others described herein. The species suggests *K. plexicostatus* Dunbar from Greenland but that species is larger, more strongly marked on the exterior and generally a more robust species. Unfortunately, enough information cannot be had on interiors of other species to make further comparison.

DISCUSSION.—The interesting feature of the species is its cardinal process. This is long and slender with parallel sides, strongly reminiscent of *Waagenoconcha*. Still more remarkable, however, is the slenderness of the buttress ridge that joins the shaft of the cardinal process to the brevisseptum. In none of the specimens is this broadly expanded where it joins the shaft, and it is difficult to understand how the buttress plates that are normal to *Kochiproductus* and usually widely spaced have been eliminated. One specimen (152735c) seems to have traces of these on the sides of the buttress ridge. In any case, the buttress plates must have been small and narrowly disposed. *Kochiproductus plexicostatus* Dunbar is similar to our species in this respect.

### *Kochiproductus* species indeterminate

Specimens of *Kochiproductus* were taken from the following localities in lots too small or too poorly preserved to be identified: Hueco Canyon Formation: AMNH 626; USNM 728d, Bone Spring Formation: AMNH 369; USNM 725y. Gaptank Formation (*Uddenites*-bearing Shale Member): USNM 701q, 702q. Skinner Ranch Formation: USNM 720e, 722-1, 727a. Hess Formation: USNM 726n. Cathedral Mountain Formation: USNM 700-1, 723k, 724n, 726x. Road Canyon Formation: USNM 726d. Word Formation (Appel Ranch Member): USNM 715i.

### *Ametoria*, new genus

[Greek *ameter* (motherless)]

Moderately large, subrectangular outline; hinge wide; pedicle valve strongly convex; brachial valve concave; no interarea or ginglymus; anterior commissure with dorsad wave; sulcus of pedicle valve prominent; fold of brachial valve not strongly developed; ears small. Pedicle valve ornamented by elongated spine bases bearing spines of two sizes as in *Juresania*; large brush of long spines at base of flanks and on ears. Brachial valve closely pitted and bearing numerous slender spines.

Pedicle valve interior with large flabellate diductor scars separated by linear adductor field, narrow and only slightly elevated.

Brachial valve interior with stout, fairly long-shafted cardinal process with myophore facing dorsad as in *Echinaria*. Lateral ridges narrow; adductor field strongly posterior, not strongly thickened and with faintly dendritic scars. Median septum thin and delicate, low, extending to base of cardinal process but not thickened to form buttress. Anterior slope strongly endospinose.

TYPE-SPECIES.—*Ametoria residua*, new species.

DIAGNOSIS.—Externally almost identical to *Juresania* Fredericks but lacking buttress plates in the brachial valve.

COMPARISON.—This genus proved difficult to place because of its obvious resemblance to *Juresania*, but with an aberrant interior in the brachial valve. That valve is similar to *Pulchratia* Muir-Wood and Cooper in that it has no buttress plates and the cardinal process is curved strongly in a dorsad direction. The median ridge of *Pulchratia* is, how-



ever, thickened posteriorly to form a buttress, or the base of the cardinal process at its junction with the valve is strongly thickened and buttressed. There is no trace of the characteristic buttress plates of the Buxtoniinae or Juresaniinae. Although the exterior of the brachial valve of *Ametoria* is like that of *Pulchratia*, the interior is very different. *Pulchratia* has the somewhat unkempt appearance of *Juresania*, produced by spines of different sizes in the posterior part, but anteriorly the genus is strongly plated and rather suggests *Echinaria*. No banding is seen in either valve of *Ametoria*.

DISCUSSION.—This is a rare genus and our material is not extensive. It does, however, show all the characters in good detail and is certainly not referable to other known genera. It is clearly an external homeomorph of *Juresania* and an internal homeomorph of *Pulchratia*.

A few young specimens in the collection that might be expected to show buttress plates, if these belonged in the ancestry of the species, fail to reveal them. They have an anteriorly excavated cardinal process meeting the hinge at about  $45^\circ$  and buttressed directly by the narrow lateral ridges that curve into the margins of the cardinal process. Indistinct reticulation marks the visceral disc of these young specimens but this seems not to be preserved in any adults. The species has been found only in the Road Canyon Formation.

### *Ametoria residua*, new species

PLATE 256: FIGURES 1–14

Medium size for productid, subquadrate in outline, length and width nearly equal; sides moderately rounded; anterior margin broadly rounded to emarginate. Hinge about equal to maximum width and produced into small, nearly rectangular ears. Surface strongly spinose, spines of three sizes: long slender spines concentrated in brush on ears, along posterior margin, and base of posterolateral slopes; oblique spines of slightly smaller diameter than preceding, oblique ( $30^\circ$  to  $60^\circ$ ) to surface and curved slightly toward valve surface; very fine, almost hairlike spines scattered among spines previously mentioned. All spines located on elongated bases, numbering three or four per 5 mm near anterior. Brachial valve with numerous spines of fairly uniform size, intermediate in size between two extremes of spines on shell body.

Pedicle valve strongly convex in lateral profile, greatest convexity in posterior half; anterior profile strongly domed, with notched crest and very steep sides. Umbonal region moderately convex and protruding moderately posterior to hinge when viewed from dorsal side. Sulcus originating on umbo, deepening anteriorly and making broadly V-shaped trench. Flanks bounding sulcus strongly inflated and narrowly rounded. Ears small and inconspicuous.

Brachial valve deeply concave with steeply dipping slopes toward midvalve; geniculation at about midvalve producing long trail; umbonal region shallowly depressed; fold not strongly developed and scarcely visible beyond midvalve in posterior direction.

Interior of both valves as described for genus.

MEASUREMENTS (in mm).—From locality USNM 703d, specimen 153476 (holotype): length 28.6, brachial valve length (hinge to front margin) 23.3, hinge width 29.7, maximum width 30.4, thickness unmeasurable.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 703, 703d.

DIAGNOSIS.—Rectangular to nearly square *Ametoria* with a strong brush of spines on the posterolateral extremities.

TYPES.—Holotype: USNM 153476. Figured paratypes: USNM 149364a-c, 154029.

COMPARISON.—No other species of the genus is known to which comparison may be made.

DISCUSSION.—This is a very rare species in the Road Canyon Formation. Immature specimens show the cardinal process to be anteriorly concave but in adult become greatly thickened. In youth the cardinal process is oblique to the hinge but in adults it bends dorsally so that the myophore faces dorsally and is clearly visible on the dorsal side of the shell. The trail is very strongly endospinose and the spines are long and thick, almost three mm long in one example.

### Subfamily JURESANIINAE Muir-Wood and Cooper, 1960

Buxtoniidae having cicatrix of attachment; ornament of lamellae, spine ridges, and two or more series of spines of different size; two vertical buttress plates extending from anterior of cardinal process, enclosing posterior end of brevisseptum and



becoming fused with septum in late growth stages.

Genus in West Texas: *Juresania* Fredericks, 1928.

Specimens of *Juresania* in the Neal Ranch Formation represent the last remnants of this once prolific genus. The specimens are extremely rare and our material is not good enough to characterize species.

*Ramavectus* Stehli, originally placed here by Muir-Wood and Cooper (1960) is shown above to be related to *Rhamnaria* Muir-Wood and Cooper, whose buttress plates are an evanescent feature.

### *Juresania* Fredericks, 1928

*Juresania* Fredericks, 1928:786, 792.—Muir-Wood and Cooper, 1960:266.—Williams et al., 1965:H492.

This genus is characterized by plano- to concavo-convex valves, the pedicle valve being ornamented by spines of two sizes and with strong bases. The brachial valve is abundantly spinose. Inside the brachial valve the cardinal process is long-shafted and supported by two buttress plates. The cardinal process may appear as a single structure or as two separate shafts that grow together in late life.

*Juresania* is based on a Russian species but is not well known in this country, nor is its identification certain. This will not be known until the interior details of the Russian species are described. Externally, however, the Russian and American specimens are similar.

In the United States this genus is identified throughout the Pennsylvanian and part of the Permian. In the latter period the genus appears not to go beyond the Neal Ranch Formation. It is best known from Wolfcampian rocks in Kansas where it can be collected in abundance and in nearly perfect condition. Good silicified specimens may be obtained in the vicinity of Dexter, Kansas, where they occur with *Derbyia cymbula* Hall and Clark. The genus is rare in the Glass Mountains and was not seen in the Hueco Group of the Hueco Mountains and Sierra Diablo.

#### *Juresania* species 1

PLATE 353: FIGURES 2-4

Specimens certainly of this genus occur rarely in the Gaptank Formation and the *Uddenites*-bearing

Shale Member. Generally they are smaller than specimens assigned to *J. nebrascensis* (Owen). One of the better preserved specimens (USNM 152736) is 19.0 mm long, the hinge width 17.6 mm, midwidth 21.0 mm, and surface length 32.0 mm. The profile is strongly convex, especially on the venter, but the trail is somewhat flattened and has a steep slope. The median sulcus is shallow and wide, extending from the venter to the front margin. The ears are small and the hinge is about equal to midwidth or less. No good brachial valves are preserved but the poor ones are moderately concave, with geniculation taking place near midvalve.

Interiors are not well preserved, except for a few fragmentary silicified specimens from USNM 701e. These show stout spines on the exterior which are rather short. The brachial valves, which are young ones (USNM 152737), have the cardinal process bilobed and the lobes separate. An old adult (USNM 152738), on the other hand, has a thick, stout cardinal process and the buttress plates buried.

Figured specimen: USNM 152736a.

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member) and Neal Ranch Formation.

LOCALITIES.—Gaptank: USNM 700e, 700f. *Uddenites*: USNM 701e, 701f, 701p, 701q, 701r, 701x, 702r, 703-1. Neal Ranch: USNM 701.

DISCUSSION AND COMPARISON.—This species may be the same as the next below but we do not have enough specimens to demonstrate the point. These specimens also suggest close relationship to a small *Juresania* that occurs in the Graham Formation. Again our specimens are not good enough nor numerous enough to prove this relationship.

#### *Juresania* species 2

PLATE 353: FIGURES 5-11

Medium size for genus, subquadrate outline, length and width subequal; sides rounded; anterior margin broadly rounded. Hinge slightly narrower than midwidth; ears small, slightly obtuse. Surface marked by radial rows of elongated spine bases of two sizes producing large and small oblique body spines. Halteroid spines forming thick brushes on ears. Concentric wrinkles few, usually along posterior margin. Brachial valve marked by small dimples separated by discontinuous ridges having ra-

dial alignment; spines small, delicate, given off at high angle.

Pedicle valve in lateral profile fairly evenly and strongly curved but with umbonal region having most curvature. Anterior profile forming fairly high dome with steep sides and slightly depressed top. Umbonal and median regions strongly swollen; sulcus inconspicuous, originating on umbonal region. Flanks gently swollen. Cicatrix small; ginglymus (or interarea) well developed in juveniles.

Brachial valve with visceral disc region nearly flat but sides and anterior margin bent abruptly in dorsal direction. Umbo concave but median region anterior to umbo forming low, flattened, barely perceptible fold.

Pedicle valve interior with large muscular field not thickened. Brachial valve interior with strong lateral ridges and stout cardinal process, bilobed in young, lobes not confluent or attached; buttress plates short, obsolete in old specimens, covered by adventitious shell growth; septum long, elevated anteriorly and reaching anterior to midvalve. Anterior slope finely endospinose.

Figured specimens: USNM 152739a,b.

MEASUREMENTS (in mm).—From locality USNM 701d, specimen 152739a: pedicle valve length 15.6, brachial valve length 13.3, surface length 23.0, hinge width 17.4\*, midwidth 19.6\*, height 8.8, thickness 7.3.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (Bed 12 of P. B. King).

LOCALITIES.—USNM 701d, 706x, 715e.

COMPARISONS.—The specimens on which this description is based are of moderately large size, but a fragment of a brachial valve indicates that the species must have attained a fairly large size for the genus. The pedicle valve of the Neal Ranch specimens appears to be somewhat less convex in lateral profile than those from the *Uddenites*-bearing Shale Member. No good brachial valves are available from the latter member for comparison with the Neal Ranch specimens.

### *Juresania* species 3

A few fragments from USNM 701 indicate a possible third species. This is coarsely ornamented, with short, stout body spines.

Mentioned specimen: USNM 152740.

## Family DICTYOCLOSTIDAE Stehli, 1954

Usually strongly geniculated Productacea having reticulate visceral region, long trail, and brachial valve with sessile or short-shafted strongly trilobed cardinal process, with prominent median lobe; adductors dendritic; brachial ridges given off horizontally.

### Subfamily DICTYOCLOSTINAE Stehli, 1954

Dictyoclostidae having the umbonal regions of both valves reticulate.

Genera in West Texas: *Spinarella* Cooper and Grant, new genus; *Xestosia* Cooper and Grant, new genus; *Nudauris* Stehli, 1954; *Rugatia* Muir-Wood and Cooper, 1960; *Spinifrons* Stehli, 1954; *Reticulatia* Muir-Wood and Cooper, 1960; *Antiquatonia* Miloradovitch, 1945; *Peniculauris* Muir-Wood and Cooper, 1960; *Dasysaria* Cooper and Grant, 1969; and *Horridonia* Chao, 1927.

This is a prolific subfamily mostly of large shells. Consequently, it has been difficult to get good material of some of the genera. The complete range of some of these genera is not yet established, *Spinarella* is confined to the Cathedral Mountain and Road Canyon formations. *Xestosia* is commonest in late Pennsylvanian and Wolfcampian rocks but ranges into the Road Canyon Formation. *Nudauris* characterizes the Skinner Ranch Formation and its lower Bone Spring correlative. *Rugatia* is confined to Cathedral Mountain and Road Canyon formations, while *Spinifrons* is chiefly Bone Spring Formation. *Reticulatia* disappears after the Lenox Hills Formation, but *Antiquatonia* ranges into the Skinner Ranch and lower Bone Spring formations. *Peniculauris* spans the Skinner Ranch, Cathedral Mountain, and Road Canyon formations. *Dasysaria* is characteristic of the Lenox Hills and Hueco Canyon formations.

### *Spinarella*, new genus

[Latin *spina* (thorn) + *ora* (edge)]

Medium size, generally rectangular outline with hinge equal to or wider than midwidth; ears large and rounded; deeply concavo-convex, with thin body cavity; shell substance commonly highly

glossy. Entire surface marked by numerous thin, low costellae crossed by concentric undulations concentrated on lateral slopes and posterior margin. Surface sparsely spinose, pedicle valve with row of long halteroid spines just anterior to posterior margin and slightly oblique, extending to extremity of ear; scattered halteroid spines rare on lateral slopes and trail; body spines scattered, small, curved, delicate. Brachial valve without spines.

Pedicle valve interior with long, narrow, sunken adductor field, diductor scars wide, deeply impressed; interior strongly granulose; anterior margin thickened.

Brachial valve interior with small sessile cardinal process having variable posterior platform; cardinal process dictyoclostid with trilobed myophore, median lobe transversely striated; lateral ridges strong; adductor field not thickened; brevisseptum strongly elevated at distal end, reaching slightly beyond mid-valve; brachial ridges strong; anterior trail slope densely but minutely endospinose.

TYPE-SPECIES.—*Spinarella perfecta*, new species.

DIAGNOSIS.—Costellate Dictyoclostidae with transverse valves, subdued reticulation, thin body cavity, depressed muscle field in the pedicle valve, low cardinal process in the brachial valve, and inner surfaces of both valves coarsely granulose.

COMPARISONS.—The thin shell, thin body cavity and transverse form of this genus are unusual for the Dictyoclostidae to which it is related because of its cardinal process. It also retains a remnant of the reticulate visceral region of the dictyoclostids, but this is usually not strongly developed. The only genus suggesting *Spinarella* among the Dictyoclostidae is *Xestosia*, which is also aberrant in having a reduction of the visceral disc reticulation and a strong development of costellae.

Internally the distinction between *Spinarella* and *Xestosia* becomes clearer and may be seen in both valves. In the pedicle valve the muscle field of *Spinarella*, with its *Yakovlevia*-like outline and elongate, depressed adductor patch, is quite unlike that of *Xestosia* which is typically dictyoclostid. Furthermore, the great thickening on the anterior side of the muscle field is unlike other dictyoclostids. Inside the brachial valve the adductor field is unlike that of *Xestosia* in being depressed and surrounded by granulose shell tissue. The strong granulation of the region between the loops of the

brachial ridges is also unusual.

Two species referred to *Xestosia*, *X. linospina* and *X. obsolescens*, are externally somewhat similar to *Spinarella*. Internally they are more like *Xestosia* than they are like the new genus.

DISCUSSION.—This genus is distinctive externally because of its subdued costellate ornament, transverse form, and generally thin body cavity. Besides the ornament on the valves, the spine arrangement is unusual for the Dictyoclostidae.

In most of the species the posterior halteroid spines form a row of progressively enlarging spines from the beak to the extremity of the ear. The spine row is slightly oblique to the posterior margin and thus descends to about the middle of the ear as the shell grows. One species, in addition to the row, has a tuft of spines on the ears. Generally the spines are long and slender for halteroid spines, but the entire makeup of the shell is delicate.

The pedicle valve interior is variable from species to species. Generally, however, the diductor scars are wide, rounded, and deeply impressed. The muscle fields are surrounded by thickened and granulose rims, and somewhat suggest *Yakovlevia*. The adductor region is unusual in being depressed and not elevated as a platform. The strong and coarsely granulose thickening on the anterior side of the muscle field is unusual, and is an important generic character.

The brachial valve of *Spinarella* is variable in many particulars. The cardinal process is usually small to medium in size and sessile. Development of a posterior platform is retarded. The cardinal process is typically dictyoclostid, with a trilobed myophore. It is commonly so low on the posterior margin that a casual glance suggests that it has been broken. The lateral ridges are usually strong and widely extended. The adductor platform varies from unthickened and nondendritic to slightly thickened and strongly depressed. The brachial ridges are usually well developed, with the inner loop thickened and elevated. The brevisseptum is long and strongly elevated distally. Small, oblique endospines cover the trail slope. The areas surrounding the adductor muscles and that between the loops of the brachial ridges are coarsely granulose; in *S. costellata*, new species, a low cone of granulose shell appears between the brevisseptum and the brachial ridge loop.

*Spinarella costellata*, new species

PLATE 381: FIGURES 1-11

Moderately convex in lateral profile, with flattened umbonal region approximately equal in length to moderately convex trail, geniculation fairly narrowly convex. Fold and sulcus fairly strong. Surface finely costellate with strong wrinkles on posterior margin and umbonal slopes. Trail obscurely costellate. Spines in single row along posterior margin and on ear extremity.

Pedicle valve interior marked by generally deeply impressed muscle field with adductor region sunken and anterior thickening of whole field strongly and coarsely granulose, and continued anteriorly along ridge formed by exterior sulcus.

Brachial valve interior with small sessile cardinal process buttressed by delicate lateral ridges. Brevisseptum low and slender. Adductor scars sunken and surrounded by coarse granules. Brachial ridges subdued, with lateral loops lying just outside two large granulose, conical mounds on each side of brevisseptum, near distal end. Small endospines forming rim at end of visceral disc.

MEASUREMENTS (in mm).—From locality USNM 703d, specimen 148842a (holotype): length 20.7, brachial valve length 17.8, surface length 37.0, hinge width 41.4\*, midwidth 33.8, height 13.7, thickness 4.6.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITY.—USNM 703d.

DIAGNOSIS.—Finely costellate, small *Spinarella* with interior strongly granulose.

TYPES.—Holotype: USNM 148842a. Figured paratype: USNM 148842b.

COMPARISONS.—This species, which is represented by only two specimens, is smaller than *S. lobata* and *S. perfecta*, both new. It is further distinguished from the former by having a much shallower sulcus and from the latter in its different proportions. Internally, it is the most strongly granulose species and is unique in having conical mounds between the brachial ridges and brevisseptum.

*Spinarella lobata*, new species

PLATE 381: FIGURES 12-36

Medium size for the genus, widely rectangular in outline, ears unusually large, rounded, and ex-

tended. Sides obliquely rounded and sloping medially; anterior margin broadly rounded and so deeply indented as to produce two lobes on each side of sulcus. Surface costellate, costellae strongest on venter and posterior part of trail, becoming obsolete or finer anteriorly. Visceral disc somewhat reticulated by concentric undulations, strongest on umbonal slopes and posterior margin and extending part way onto ears. Sparsely spinose; halteroid spines forming row along posterior margin, largest spines occupying ear extremity; halteroid spines on trail, few and slender. Body spines few, widely scattered. Visceral disc of brachial valve more strongly ornamented than pedicle valve, costellae strongly cancellated on ears but forming wavy and pitted pattern in median region and flanks.

Pedicle valve unevenly convex in lateral profile, posterior third flatly convex, median third narrowly rounded, and anterior third or trail moderately convex. Anterior profile broad, steep-sided dome, deeply indented medially and side forming two narrowly rounded humps. Umbonal region flatly convex and with short gentle slopes; umbonal region slightly protruding beyond posterior line when viewed from dorsal side. Sulcus originating on anterior side of umbonal region, deepening anteriorly and forming strong indentation at anterior of trail. Flanks narrowly rounded and with steep sides.

Brachial valve closely molded to pedicle valve, thus producing thin visceral cavity; deepest slightly anterior to midvalve, there two depressions separated by carinate and strong median fold originating on anterior side of umbonal pit. Ears deeply concave and defined by gentle, oblique folds.

Pedicle valve interior with wide muscle field, diductors triangular; adductor field depressed medially but bounded by two ridges. Area surrounding muscle field and ridges bounding adductor area strongly and grossly granulose.

Brachial valve interior with low, sessile, dictyoclostid cardinal process; lateral ridges well formed but short; ridge buttressing cardinal process short; adductor scars sunken and surrounded by strongly granulose shell; brachial ridge well developed with inside loop thickened; brevisseptum long and slender. Anterior geniculated to form short trail densely covered by short, slender, and delicate endospines.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 707c							
148843a	20.0	16.9	36.0	39.8	25.1	13.5	7.3
(holotype)							
148843b	19.8	16.6	32.0	43.4	27.9	11.8	6.0
148843c	19.9	18.0	33.0	39.0*	27.6*	12.5	3.8
148843d	18.6	16.1	27.5	37.4*	26.6	9.5	2.7
148843e	20.7	17.2	32.0	43.6	26.9	13.3	4.3
152741a	22.5	19.0	43.5	47.3	34.8	17.0	6.0
152741b	25.3	20.2	45.0	42.0	33.7	16.6	9.4
152741c	22.3	18.0	44.0	46.6*	30.8*	16.6	6.2
152741d	20.0	17.6	35.0	45.4*	33.0*	13.2?	4.4
152741e	26.4	21.4	44.0	45.0*	31.0*	16.7	5.9
152741f	18.5	16.5	29.0	37.3	29.6	9.6	2.1

Specimens 148843a–e strongly lobate, 152741a–f moderately lobate.

LOCALITIES.—USNM 707e, 719x, 723x.

DIAGNOSIS.—Widely transverse anteriorly lobate and deeply sulcate *Spinarella* with strongly sculptured brachial valves.

TYPES.—Holotype: USNM 148843a. Figured paratypes: USNM 148843e, f, 154010a, b. Measured paratypes: USNM 148843b–e, 152741a–f. Unfigured paratypes: USNM 148843b–d, 152741a–f.

COMPARISONS.—In its great width, both along the hinge and the body, this species is distinguished from other Glass Mountains species. It is separated from *S. perfecta*, new species, which it resembles internally, by its more lobate form, stronger and more prominent ears, and the peculiar irregular ornament of the brachial valve.

DISCUSSION.—The collection of this species consists of 25 specimens, only a few of which are alike. They vary from the strongly lobate forms (148843a) to one specimen (148843g) which is scarcely lobate and has proportions somewhat at variance from the others. It forms a poorly lobate end member of the series and is included in the species because its ornament is like that of the other specimens.

*Spinarella paulula*, new species

PLATE 379: FIGURES 1–27; PLATE 380: FIGURES 17, 18

Medium size for genus, transversely and narrowly rectangular in outline; hinge forming widest part; sides narrowly rounded; anterior margin broadly

rounded. Anterior commissure with slight dorsad median wave. Beak small, umbo not protruding strongly beyond hinge. Ears small, truncated. Surface with visceral disc region of both valves obscurely reticulated and trail with indistinct narrow costae. Spines thin, numerous, forming single row from beak across posterior to the ends of ears; scattered thin spines elsewhere on visceral disc and trail. No spines on brachial valve.

Pedicle valve strongly convex in lateral profile, maximum convexity in posterior part; anterior profile broad high dome somewhat broadly flattened on top and with steeply sloping sides. Umbonal and medial regions strongly inflated. Sulcus originating on umbo, shallow and widening anteriorly, deepest at front but shallow throughout. Anterior margin slightly notched; flanks strongly swollen and steep-sided; ears depressed, narrowly rounded, and laterally truncated.

Brachial valve deeply concave, umbo depressed; deepest at midvalve; ears separated by strong oblique ridge; ears deeply concave; anterior and lateral slopes steep.

Pedicle valve interior with flabellate diductor scars and anteriorly thickened and elevated adductor track. Brachial valve interior with small, sessile trilobed cardinal process; lateral ridges, narrow, carinate, and fairly strongly elevated; brevisseptum thin and delicate; adductor scars small, moderately thickened; brachial ridges narrow and slightly thickened.



MEASUREMENTS (in mm).—

	length	brach- ial valve length	sur- face length	hinge width	mid- width	thick- ness
USNM 702c						
149527a	23.2	19.9	43.0	38.9	31.5	5.7
149527b	23.2	19.1	42.5	36.5	29.2	5.7
149527c	23.6	17.6	44.0	38.2?	30.0	6.0
149527d	14.1	12.6	18.0	18.6	19.7	2.7
149527e	17.3	15.0	28.0	23.4	23.0	3.8
USNM 719x						
153470a	25.2	18.5	47.0	36.9	31.3	8.2?
(holotype)						

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 702c, 716x, 719x.

DIAGNOSIS.—Medium *Spinarella* with a row of thin and delicate spines along the posterior margin and with thin, scattered spines on the shell body.

TYPES.—Holotype: USNM 153470a. Figured paratypes: USNM 149527b, c, d, g, h; 153470b–d. Measured paratypes: USNM 149527a–e. Unfigured paratypes: USNM 149527a, e, f.

COMPARISON.—This species is easily distinguished from *S. lobata*, new species, by the very shallow sulcus on the pedicle valve compared to the deep trough in the pedicle valve of *S. lobata*. It is a much smaller species than *S. perfecta*, new species, with a shallower sulcus, and more rounded ears, which are laterally truncated. In size, it is more like *S. costellata*, new species, but it has a shallower sulcus, less reticulate visceral disc, much lower umbonal region, and is not provided with the strong spinosity of the interior that is so characteristic of *S. costellata*.

DISCUSSION.—The collection of this species includes some young specimens that are nearly flat and without ears before they attain a length of 16 mm.

*Spinarella perfecta*, new species

PLATE 379: FIGURES 28–35; PLATE 380: FIGURES 1–16

Large, transversely rectangular, hinge extended laterally beyond midwidth; sides gently curved and sloping medially; anterior margin broadly rounded and fairly deeply indented medially. Ears large, convex, narrowly rounded to bluntly pointed. Costellae numbering five to seven per 5 mm on trail just anterior to venter, strongest on visceral disc and venter, becoming obsolete on anterior part of trail. Slopes between ears and beak marked by strong concentric undulations cancellating costellae on visceral disc and umbonal slopes. Brachial valve similarly marked. Surface sparsely spinose; row of fine halteroid spines obliquely extending from umbo to ear extremities, several spines there forming small tufts. Additional halteroid spines scattered on trail, usually near anterior margin. Body spines small and well scattered.

Pedicle valve unevenly convex in lateral profile, visceral disc region shorter than trail and flatly convex, venter narrowly rounded; trail long and gently curved. Anterior profile forming wide dome depressed medially and with long, steep slopes extending to ears. Umbo slightly protruding posterior to posterior margin; umbonal region moderately swollen and moderately steep slopes to ears; sulcus originating on anterior side of umbonal region, narrowly and deep on venter, extending to anterior margin with little shallowing. Flanks bounding sulcus narrowly rounded.

Brachial valve deeply concave and molded to pedicle valve to form thin body cavity; umbonal region wide, deeply depressed, deepest at midvalve, with precipitous sides and anterior. Ears large and deeply concave, marked off by oblique fold.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702c							
148844a	31.4	23.7	64.0	44.8*	39.6	21.0	9.9
(holotype)							
148844b	26.7	21.7	50.0	49.0	34.5	17.3	?
148844c	29.4	23.3	60.0	51.2	42.1	25.3	10.1
148844d	24.2	20.7	47.0?	46.9	35.9	19.4	7.0
148844e	24.5	21.0	42.0	47.9	33.4	15.9	?
148844f	22.3	17.0	33.0?	38.2	28.2	10.9	2.0

Pedicle valve interior with poorly developed adductor platform, and with strongly granulose thickening surrounding muscle field. Brachial valve interior with small cardinal process and slender, short, lateral ridges; adductor field with muscle marks poorly defined; brevisseptum not strongly elevated at anterior; brachial ridges strong, area posterior to them, inside lateral loop, swollen and coarsely granulose; endospines forming fringe at edge of visceral disc.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 702c, 721r, 726d.

DIAGNOSIS.—Large, transverse *Spinarella* with numerous fine body spines and a single row of posterior halteroid spines.

TYPES.—Holotype: USNM 148844a. Figured paratypes: USNM 148844c,e,h-j. Measured paratypes: USNM 148844b-f. Unfigured paratypes: USNM 148844b,d,f,g.

COMPARISONS.—Internally this species is allied to *S. lobata*, new species, but the two are completely unlike in external appearance. Although deeply sulcate and anteriorly emarginate, *S. perfecta* is much larger and less lobate than the other species. *Spinarella perfecta* has proportions similar to those of *Xestosia obsolescens*, new species, but the latter species is shallower on the dorsal side and less convex on the ventral side. Furthermore the ears of *X. obsolescens* are strongly tufted, which makes another easy distinction between the two.

DISCUSSION.—*Spinarella perfecta* is an uncommon species and is known only from two localities. Generally very thin-shelled, it is difficult to recover in one piece from residues; it is even more difficult to obtain separate valves in good condition. Internally it is characterized by the strong granulation of both valves.

### ***Xestosia*, new genus**

[Greek *xestos* (smoothed)]

Transversely rectangular outline, hinge forming widest part; ears large, extended. Deeply concavo-convex and strongly geniculated anteriorly; pedicle valve sulcate. Surface variable, with subdued and delicate costellae and subdued concentric undulations producing mild reticulation. Spines scattered; halteroid spines in more than one descending row

on posterior margin and ears and usually forming fine brush; fine, delicate body spines scattered on visceral disc and few stout halteroid spines on trail; no spines on brachial valve.

Pedicle valve interior with concave ears separated from visceral cavity by oblique fold; adductor field on ridge produced by sulcus, not greatly thickened in young but well elevated in adult and old shells; diductor scars flabellate; interior, outside muscle field, finely granulose.

Brachial valve interior with low cardinal process having deeply indented median lobe in ventral view; cardinal process trilobed in posterior view and with strong lophidium. Lateral ridge strong, not forming ear baffles. Brevisseptum anteriorly elevated; adductor field not thickened, strongly dendritic. Anterior slope strongly but finely endospinose.

TYPE-Species.—*Xestosia obsolescens*, new species.

DIAGNOSIS.—Transverse Dictyoclostidae with subdued ornament, spiny ears, and sessile cardinal process.

COMPARISONS.—The subdued ornament and spiny ears of this genus are distinctive and separate it from most other genera. It suggests *Nudauris* Stehli but that genus is more liberally provided with stout spines on the body of the shell and trail and has only a single row of spines on the posterior margin and ears. It is also more strongly ornamented with costae and with stronger undulations. The large dictyoclostid cardinal process of *Chaoiella* Fredericks separates that genus from *Xestosia*, although the surface ornament is similar in many details. *Spinarella*, new genus, has similar exterior characters but differs in the nature of the pedicle muscles and the degenerate form of the cardinal process.

Many species of *Xestosia* resemble Mississippian and Pennsylvanian *Inflatia* Muir-Wood and Cooper, but significant differences appear in details of the exterior and interior. Species of *Xestosia* are generally strongly transverse, whereas those of *Inflatia* are square or elongate rectangular and with nearly parallel sides. *Inflatia* does not have strongly extended ears as does *Xestosia*, and the ornamentation of the trail is stronger over the whole surface. The trail of *Xestosia* usually becomes smooth in the adult. Inside the pedicle valve the adductor field of *Inflatia* is greatly thickened but that of *Xestosia* is not. Likewise, in the brachial valve the visceral region is demarcated by an anterior thickening and most of the structures are strongly developed. This

is not true of *Xestosia*, which usually has delicate structures in the brachial valve interior.

*Xestosia obsolescens*, new species

PLATE 382: FIGURES 11–26

Large, transversely rectangular outline, hinge forming widest part. Ears large, convex, and rounded. Sides rounded; anterior margin broadly rounded and broadly indented at middle. Ornament subdued, visceral disc region faintly reticulate, concentric undulations strongest on umbonal slopes and adjacent posterior margin. Venter and trail costellate, costellae somewhat irregular, usually indistinct, numbering about five per 5 mm on trail. Halteroid spines usually posteriorly located, consisting of two or three rows oblique to posterior margin, largest and longest spines located on ears; tuft of ear spines consisting of long slender spines attaining length of 50 mm and usually extending directly laterally. Body with short and delicate ornament spines. Halteroid spines occasionally occurring on trail. Brachial valve with similar ornament and with strong concentric undulations over folds demarcating ears, but without spines.

Pedicle valve unevenly convex in lateral profile,

posterior third somewhat flattened, median region narrowly convex, trail gently convex but more so than visceral disc region. Anterior profile broadly domed, median region deeply depressed, flanks narrowly rounded, steep-sided. Umbonal and visceral disc regions gently convex, with short slopes and not protruding posterior to posterior margin in dorsal view. Sulcus originating on visceral disc, broad and shallow on venter but becoming deeper anteriorly.

Brachial valve deeply concave, with large ears well-demarcated and shallow; deepest at midvalve on both sides of median fold; sides and anterior steep; fold originating posterior to midvalve, low and broad and causing dorsad wave in margin.

Pedicle valve interior with adductor field slightly elevated; diductor scars flabellate and striate. Anterior trail slope and sides at ears strongly but minutely granulose.

Brachial valve interior with depressed and partially resorbed cardinal process, myophore commonly flush with or below lateral ridges; adductor field small, not thickened, dendritic. Breviseptum long and delicate. Brachial ridges well developed, with inner loop elevated and thickened. Anterior trail slope minutely endospinose.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702un							
148861a	27.2	21.6	?	46.8*	41.9	15.3	8.0
148861b	28.6	24.4	54.0	50.1	39.0	19.8	8.3
(holotype)							
148861c	29.0	23.9	50.0?	48.4*	38.7	15.5	5.9
148861d	28.7	25.8	50.0	53.8	43.4	18.8	6.3
148861e	27.9	23.6	49.0	50.3	39.2	18.1	8.0
148861f	28.5	23.2	53.0?	46.6	37.8	18.7	8.1
148861g	29.0?	23.2	58.0	53.2	40.6	29.5	11.7

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITIES.—USNM 702, 702un.

DIAGNOSIS.—Transverse *Xestosia* with subdued ornament and a narrow tuft of long, slender halteroid spines on the ears.

TYPES.—Holotype: USNM 148861b. Figured paratypes: USNM 148861a, g, h, j, k. Measured paratypes: USNM 148861a, c-g. Unfigured paratypes: USNM 148861c-f, i.

COMPARISONS.—This species is internally most like *Nudauris linospina*, new species, in having an elevated adductor field in the pedicle valve and low cardinal process in the brachial valve. The similarity ends there, however, because its exterior is totally unlike that of *N. linospina*. The body outline is much more transverse than that of *N. linospina* and it has a luxuriant tuft of spines on the ears whereas the latter is provided with a single row of posterior halteroid spines.

*Xestosia schucherti* (R. E. King)

PLATE 366: FIGURES 1-3; PLATE 367: FIGURES 3-6; PLATE 371: FIGURES 14?, 15?; PLATE 382: FIGURES 1-10; PLATE 383: FIGURES 1-13

*Productus schucherti* R. E. King (part), 1931:73, pl. 15: figs. 3a,b, 4a-c, 5? [not figs. 1, 2].

Large for genus, widely rectangular in outline, large, rounded ears laterally extended; sides sloping medially; anterior margin broadly rounded and slightly indented medially. Costellae low and narrow, numbering five or six on trail of large specimens, interspersed with short costae on anterior part of trail. Spines forming up to three oblique rows along posterior margins and on ears, where rows form flat brush. Spines on shell body few; scattered halteroid spines on trail.

Pedicle valve unevenly convex in lateral profile, maximum convexity on venter; visceral disc flattened but trail moderately swollen. Anterior profile swollen, steep-sided dome with median depression and rounded flanks. Beak low; visceral

region depressed, convex; sulcus broadly V-shaped, shallow, originating on anterior part of visceral disc and extending to anterior margin. Flanks strongly rounded. Trail long and convex, longer than visceral region. Umbo low and inconspicuous in dorsal view.

Brachial valve deeply concave; umbo forming shallow pit under beak; ears deeply concave, set off from visceral region by strong ridge; shell deepest on each side of low, subcarinate fold. Sides and anterior precipitous.

Pedicle valve interior with lightly impressed muscle scars; diductors broadly flabellate; adductor track slightly elevated; adductors elongate, dendritic. Ears demarcated by rounded ridge.

Brachial valve interior with strong subcarinate lateral ridges extending onto ears; cardinal process short, deeply indented, and bilobed on ventral face, trilobed on posterior face and with recessed median lobe. Adductor scars triangular dendritic; brachial ridges well formed and with elevated rim. Endospines on geniculate areas over trail, numerous and strong.

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
King 120							
YPM 10763b (lectotype)	25.3?	?	?	?	33.0*	15.7	?
YPM 10763a (paratype)	20.8	19.3	?	?	29.7	?	6.9
USNM 721u 152744a	27.2	18.8	54.0	53.0	36.0	19.4	8.8

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation (Wedin Member), Cibolo Formation (Spicule Zone of Udden).

LOCALITIES.—King 120. Cathedral Mountain: USNM 707q, 709, 709o, 711q, 712o, 721u, 724k, 724n, 730u. Wedin: USNM 714w. Cibolo: USNM 739k.

DIAGNOSIS.—Fairly strongly costellate *Xestosia*.

TYPES.—Lectotype: YPM 10763b. Figured paratypes: YPM 10763a, 10764. Figured and measured hypotype: USNM 152744a. Figured hypotypes: YPM 10762, USNM 153998 b-g. Figured specimen: USNM 148867.

COMPARISON.—This species suggests *X. obsolescens*, new species, in size and exterior form but it is strongly costellate compared to the faint ornament of *X. obsolescens*. It is wider and generally larger as well as more strongly costellate than *Nudauris lino spina*, new species. It is also provided with more spines along the posterior margin and on the ears than the other species.

DISCUSSION.—This is an uncommon species, and usually it is difficult to obtain good specimens. Some ambiguity exists about King's locality 120 which is cited (1931:135) as "0.6 mile east of hill 4910" (our USNM 721u) but is located on his map

as a half mile south of this point (our USNM 712o). Our collections include this species from both localities. Consequently, they may be regarded as topotypes, and a fairly clear idea of the species may be had from some fine silicified material. The only specimens listed as cotypes are from King locality 120, where the species is listed (King 1931:73) as abundant and the additional word "types" added. It seems clear that he regarded the specimens from this locality as typical. From these, then, the lectotype must be selected.

This species is based on six cotypes, five of them belonging to Yale University and one to the University of Texas. The latter (T 10311) is a large specimen from the Bone Spring Formation in the Sierra Diablo at King locality 484. This is the largest of the specimens and is rejected as atypical if King's species is to be based on a specimen with extended ears. The ears of this one are extended but not strongly so.

Of the five Yale specimens, one (YPM 10762) is unfigured but is, nevertheless, marked as one of the cotypes. This specimen is large, almost as large as the University of Texas specimen mentioned above, and the ears are moderately extended. Like the preceding, it comes from King locality 484, and is rejected as atypical.

Of the figured specimens one is a fragmentary silicified specimen from King locality 484 and is undoubtedly conspecific with the two previously mentioned specimens from the Sierra Diablo. Like the others, this one is also rejected.

The fourth specimen (YPM 10764) was not figured; it is from northeast of Word Ranch (King 174) and is from the Leonard. The specimen is very poorly preserved and is quite unlike all of the others, being suggestive of specimens of *Nudauris linospina*, new species, which is common in the vicinity of Split Tank, and it is excluded from *Productus schucherti*.

The fifth Yale specimen (one of a lot of two) had a large ear like those from USNM 721u. The better of the two, YPM 10763a (King 1931, pl. 15: figs. 4a-c), is selected as lectotype.

The sixth specimen comes from the Delo collection (locality D1) and is from Leonard Mountain. It may be conspecific with the two preceding but without knowledge of its stratigraphic horizon we cannot regard it as a paratype.

### Genus *Nudauris* Stehli, 1954

*Nudauris* Stehli, 1954:317.—Muir-Wood and Cooper, 1960:228.—Williams et al., 1965:H482.

Large, transversely rectangular in outline, hinge forming widest part; ears large and conspicuous, angular to bluntly rounded. Deeply concavo-convex, with narrow visceral chamber. Pedicle valve strongly sulcate; brachial valve with low, carinate fold. Surface obscurely costate, costae without regularity and variable in size, strongest on visceral disc and venter, becoming sparse to obsolete anteriorly; visceral disc crudely reticulated by strong concentric undulations. Spines mostly of halteroid type, sparsely distributed; in row slightly oblique to posterior margin and terminating on ear extremity; trail spines scattered and few in number; body spines small, mostly on visceral disc region. Brachial valve without spines.

Pedicle valve interior with transversely oval adductor scars; adductor field elongate, generally confined to ridge formed by sulcus of exterior. Interior around visceral region minutely granulose.

Brachial valve interior with small trilobed dictyoclostid cardinal process; lateral ridge strong; anteromedian buttress to cardinal process variable, absent to strong; adductor field small, rhombic in outline, scars dendritic; brachial ridges well developed; brevisseptum delicate, extending slightly anterior to midvalve; endospines on margin of visceral disc region thick and numerous; trail slope with mat of fine endospines.

**TYPES-SPECIES.**—*Nudauris diabloensis* Stehli (1954:317, pl. 21: figs. 1–5).

**DIAGNOSIS.**—Transverse Dictyoclostidae with irregular ornament, a row of posterior halteroid spines and few spines on the body.

**COMPARISONS.**—*Nudauris* is distinguished from related genera chiefly by its exterior characters. The indefinite nature of the ornament with its mixed costae and costellae, the crude nature of the reticulation on the visceral disc, and sparse spines are important features. *Nudauris* is most like *Chaoiella* Fredericks, but can be distinguished by its much more transverse valves, less distinctly reticulate visceral region, and the more strongly ornamented trail. In individual examples it may be difficult to separate two specimens of these genera, but in fairly large collections the distinction is easy.

**DISCUSSION.**—The exterior characters of this ge-



nus have been mentioned in the comparisons with other genera. The ornament is extremely variable, but the arrangement of the spines seems more regular. Halteroid spines are developed along the posterior margin; but in progressing outward and in order of growth the spines become larger and descend somewhat anteriorly, so that the last formed and largest spine is located on the extremity of the ear. Halteroid spines are also developed on the trail slopes, especially in the anterior part. The lateral slopes, which in many genera are the sites of numerous spines, are generally adorned with only a few spines in this genus. The visceral disc region bears a few scattered small spines.

Inside the pedicle valve the sulcus of the exterior makes a prominent ridge that runs from the umbonal chamber to the anterior margin. At its posterior end this is the seat of attachment for the adductor muscles, which form an elongate but only modestly thickened scar. The diductor scars are crudely circular patches whose rounded ends lie just anterior to the anterior end of the adductor field.

The ears of the pedicle valve of *Nudauris* are deeply concave and large. They are not bounded at their proximal side by any sort of baffle but their floor is granulose. The granules are fine and delicate and cover most of the interior outside the muscle field.

The brachial valve interior has fairly well-developed lateral ridges that die out just before the ears are reached and do not form baffles. The cardinal process is moderately large and bilobed from the ventral side. The median lobe in this view bears a deep depression. The lophidium is small and fairly strongly elevated. The myophore is distinctly trilobed, with the two lateral lobes moderately to widely divergent. The median lobe is usually narrow and in some specimens is directed posteriorly, so that the cleft in its ventral face is visible from the posterior. This is similar to a marginiferoid cardinal process, but not all specimens exhibit this feature. The adductor field is moderately thickened, with the outer muscle scars somewhat kidney-shaped and the inner scars tear-shaped. All scars are strongly dendritic. A rounded median ridge supporting the cardinal process is developed in some specimens but is usually not produced anteriorly to join the brevisseptum. The latter structure is delicate and strongly elevated at its free end. The

brachial ridges are usually well-developed and have thickened rims. The anterior margin of the visceral disc at the place of geniculation is covered by thick, stubby endospines.

### *Nudauris convexa*, new species

PLATE 371: FIGURES 1-3

Medium size to large for genus, wider than long, greatest width along hinge; ears prominent, subangular. Sides gently rounded; anterior margin broadly rounded and slightly indented. Visceral disc region of both valves fairly strongly reticulate; venter strongly costellate with about 5 costellae per 5 mm. Costellae on trail very fine to obsolete; trail marked by occasional longitudinal wrinkles; lateral slopes marked by strong concentric undulations. Spines sparse; occurring in row slightly oblique to posterior margin and terminating on ear extremity; scattered on trail.

Pedicle valve unevenly convex in lateral profile, trail much longer than flatly convex visceral disc region, venter narrowly rounded and trail moderately convex; anterior profile, high steep-sided dome without median indentation. Umbonal region somewhat narrowly convex but merging into flattened visceral disc region; umbonal slopes short and moderately steep. Sulcus poorly defined, originating on anterior side of visceral disc, broad and barely discernible on trail.

Brachial valve deeply concave, with steep anterior and sides; umbonal depression shallow, visceral disc gently concave; anterior part of visceral disc and trail with barely perceptible fold.

Pedicle valve interior unknown. Brachial valve with stout dictyoclostid cardinal process buttressed by strong lateral ridges and moderately thickened median ridge. Adductor field not strongly thickened, dendritic.

MEASUREMENTS (in mm).—From locality USNM 705, specimen 152742 (holotype) and from 715b, 152743, respectively: length 27.5, 26.3; brachial valve length (?), 21.9; surface length 60.0, 53.0; hinge width 30.4+, 47.4\*; midwidth 34.5, 36.2; height 18.7?, 17.8; thickness (?), 8.9.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation; Lenox Hills Formation.

LOCALITIES.—Neal Ranch: USNM 715b; Lenox Hills: USNM 705, 716r.

DIAGNOSIS.—Medium-sized to large *Nudauris* having a poorly defined median sulcus.

**TYPES.**—Holotype: USNM 152742. Unfigured and measured paratype: USNM 152743.

**COMPARISON.**—This is a large species for the genus and suggests *N. reticulata*, new species. It is distinguished by its much more robust form, less deep sulcus, and presence of costae in addition to costellae on the trail.

**DISCUSSION.**—This rare species was not found in any of the localities for silicified fossils. It is usually difficult to get abundant material in beds that do not contain silicified fossils.

### *Nudauris diabloensis* Stehli

PLATE 372: FIGURES 1–20

*Productus schucherti* R. E. King, 1931:73, pl. 15: figs. 1, 2 [not figs. 3–5].

*Nudauris diabloensis* Stehli, 1954:317, pl. 21: figs. 1–5.

The figures of Stehli's type specimens do not show clearly the type of ornament of this species. Additional specimens indicate costae of two sizes and a fairly strongly reticulate visceral disc. The sulcus is deep and the trail marked by fine costae of fairly even size, with larger costae scattered among them, some induced by the presence of large spines. Although the visceral disc is reticulated, the undulations are strongest laterally and are fairly distant from one another.

The spines consist mostly of halteroid spines, a row descending anteriorly from the posterior margin and terminating with the largest spine on the ear, a fact that makes the name of the genus inappropriate. The visceral disc and most parts of the trail bear large, stout but distantly scattered spines.

**MEASUREMENTS** (in mm).—Thickness unmeasurable.

	length	brach- ial valve length	sur- face length	hinge width	mid- width	height
USNM 728f						
152748a	36.5	25.0	67.0	61.0	44.6	24.6
152748b	34.2	24.4	62.0	51.0	42.7	21.9
152748c	32.4	25.7	61.0	51.6	43.0	23.2
152748d	34.4	25.6	67.0	63.0*	48.0	24.5
152748e	28.0	25.6	41.0	39.4	41.6	14.6
152748f	?	25.6	?	49.6	42.3	?

**STRATIGRAPHIC OCCURRENCE.**—Bone Spring Formation (lower).

**LOCALITIES.**—AMNH 625, 629; USNM 728e, 728f.

**TYPES.**—Figured hypotypes: USNM 152748a, b,

f; 153985a, b. Measured hypotypes: USNM 152748a–f.

### *Nudauris enigmatica*, new species

PLATE 371: FIGURES 4–9, 10–13?

Large for genus, strongly geniculated; wider than long, outline subrectangular. Sides gently rounded; anterior margin broadly rounded. Ears moderately large and extended, hinge forming widest part. Surface semireticulate; reticulation on visceral disc of pedicle valve coarse, regular on lateral slopes where undulations are strongest, less so on umbonal and median regions; brachial valve visceral disc somewhat more regularly reticulate; trail marked by costellae and costae, costae generally developing anterior to large halteroid spine. Radial elements irregular, about 4 or 5 finer ones occupying 5 mm on trail slope. Spines irregularly distributed; tuft of strong halteroid spines on ears and large ones scattered on trail slope, especially in anterior half. Brachial valve pitted corresponding to large halteroid spines.

Pedicle valve with strongly convex lateral profile, convexity so strong that tangents to umbonal regions and anterior trail slope are nearly parallel. Umbonal region flatly convex and with moderately steep but short umbonal slopes. Median region strongly swollen. Sulcus originating on anterior side of umbonal region, moderately deep but narrow and extending to anterior margin. Flanks bounding sulcus well rounded, lateral slopes steep.

Brachial valve deeply concave, most concave at place of geniculation and with steep sides and anterior. Visceral disc region moderately concave; fold narrow, low, and originating just anterior to shallow umbonal depression.

Pedicle valve anterior with strongly dendritic adductor field located on low, slightly thickened ridge. Brachial valve interior with fairly broad posterior platform extending laterally into narrow, sharp lateral ridges not quite extending to margins. Cardinal process low, trilobed, and with small median lobe. Adductor scar large, moderately thickened, rhomboidal in outline, and dendritic. Brachial ridges large, with thickened rims. Anterior slope covered with fine, short endospines.

**STRATIGRAPHIC OCCURRENCE.**—Skinner Ranch Formation (Decie Ranch, Poplar Tank, and Sullivan Peak members).

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 708e							
152749a	38.0	32.0?	81.0	56.4*	45.0?	24.3	?
152749b	37.5	?	74.0?	57.6	40.0?	22.0	10.0
152749c	?	30.1	?	44.8*?	41.6	?	?
152750b	30.9	?	77.0?	66.6*	48.2	23.8?	?
(holotype)							

LOCALITIES.—Decie Ranch: USNM 707a, 714t. Poplar Tank USNM 703y, 707ha. Sullivan Peak: USNM 708e, 710r. Skinner Ranch: USNM 705a, 711d, 719y, 720e, 723–1, 726h.

DIAGNOSIS.—Large *Nudauris* with strongly reticulate and well-defined visceral disc region and long trail.

TYPES.—Holotype: USNM 152750b. Figured paratype: USNM 152750a. Measured paratypes: USNM 152749a–c. Unfigured paratypes: USNM 152749a–c. Figured specimen: USNM 153984.

DISCUSSION.—This species is rare in the Glass Mountains and is unusual in silicified form. It occurs silicified at USNM 705a but the single specimen is badly crushed. Most of the material studied was obtained by cracking from the rock, consequently no complete specimens were taken.

*Nudauris linospina*, new species

PLATE 368: FIGURES 1–29; PLATE 369: FIGURES 21–29; PLATE 410: FIGURES 1–8

Medium size for genus; shell glossy, wider than long and transversely subrectangular in outline. Hinge forming widest part. Ears large, angular to narrowly rounded. Sides gently rounded; anterior margin broadly rounded and strongly indented medially. Surface costellate; visceral disc obscurely reticulate; umbonal slopes and posterior margin marked by strong concentric undulations; costellae numbering about 4 or 5 per 5 mm on trail. Surface sparsely spinose; row of long halteroid spines oblique to posterior margin and terminating on end of ear where largest spine is located; occasional large halteroid spines on trail; body spines, small, slender, scattered.

Pedicle valve lateral profile unevenly convex, median region narrowly convex, visceral disc region gently convex to flattened and slightly less convex

than anterior, or trail, region, which is gently convex and nearly equal in length to visceral region. Anterior profile high steep-sided dome indented medially, indentation bounded by narrowly rounded flanks. Visceral disc region slightly swollen but generally flatly convex, low and inconspicuous in dorsal view; umbonal slopes short. Median region inflated. Sulcus originating on visceral disc, narrow, moderately to strongly deep and continuous to anterior margin. Flanks strongly rounded.

Brachial valve closely molded to pedicle valve, very deep; ears moderately concave and well demarcated by oblique fold; sides and anterior slopes steep; fold originating near midvalve, low and subcarinate.

Pedicle valve with thick adductor platform and narrow elongate diductor scars, posterior being considerably thickened and muscles deeply inserted.

Brachial valve interior with cardinal process reduced and low; adductor field only slightly thickened but adductor scars dendritic; lateral ridges strongly developed; brachial ridges with inner loop thickened.

MEASUREMENTS (in mm).—Holotype brachial valve length 22.0 and thickness 8.3; of others, these are unmeasurable.

	length	surface length	hinge width	mid- width	height
USNM 702					
148845a	21.8	34.0?	33.3	28.3	12.6
148845b	24.2	44.0	33.0	29.3	15.6
148845c	25.5	49.0	35.7	28.4	17.5
148845d	22.4	38.0	35.3	30.3	14.3
148845e	24.2	42.0	37.7	31.0	14.8
148845f	24.8	46.0	42.0	34.5	16.0
148845g	30.7	57.0	44.9	41.0	20.6
148845h	33.7	61.0	48.2	40.9	22.7
148856c	28.5	54.0	48.2	39.0	20.2
(holotype)					

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITIES.—USNM 700-l, 702, 702a, 702b, 702 inst., 702-low, 702un, 703a<sup>1</sup>, 703b, 707q, 711q, 711r, 723y, 724i, 726o, 726u, 726w, 726y, 727q, 733m, 735b.

DIAGNOSIS.—Medium-sized, compact *Nudauris* with the length about four-fifths the body width.

TYPES.—Holotype: USNM 148856c. Figured paratypes: USNM 148846d; 148856a, b; 148860a-c; 148862a, c; 148863a, b; 153944a, b; 153982a-c; 153983. Measured paratypes: USNM 148845a-h. Unfigured paratypes: USNM 148862b, 148846a-c; 153982a, c.

COMPARISONS.—This species in its compact form is unlike any other in the Glass Mountains. It is distinguished from *Xestosia obsolescens*, new species, which it most resembles, in the smaller ears, more nearly square body, and the presence along the posterior margin of a single row of halteroid spines.

This species is fairly common in the shaly beds of the Cathedral Mountain Formation just above the zone with *Institella* Cooper and *Torynechus* Cooper and Grant. The brachial valve interior of this species is imperfectly known but it is most like that of *X. obsolescens* in having an elevated adductor field and the sunken myophore of the cardinal process.

### *Nudauris presplendens*, new species

PLATE 369: FIGURES 1-5

Medium size for genus, transversely rectangular in outline, with highly lustrous shell (not silicified) when fresh or exfoliated. Ears prominent; sides sloping medially; anterior margin somewhat truncated and strongly reentrant medially. Hinge slightly wider than midwidth. Umbo low; beak small. Surface marked by low, rounded, closely

crowded costellae, about seven per 5 mm on trail and becoming fainter anteriorly. Halteroid spines forming single row along posterior margin and on ears, few strong ones scattered on trail slope.

Pedicle valve unevenly convex in lateral profile, geniculation separating flattened posterior third from flattened to slightly convex anterior third; angle of geniculation varying from about 60° to 80°. Anterior profile a broad dome indented deeply medially and with steeply sloping sides. Umbonal and visceral regions flattened, with low convexity. Sulcus deep, broadly V-shaped, variable but usually deep and strongly indenting anterior margin. Flanks narrowly rounded. Ears somewhat flattened, varying from slightly acute to nearly a right angle.

Brachial valve broadly concave; umbonal region deeply depressed; ears deflected and demarcated by oblique, rounded ridges; fold low and narrow, strongest on anterior slope and across deepest part of shell at midvalve.

Interior not known.

STRATIGRAPHIC OCCURRENCE.—Graham Formation (Finis and Jacksboro members).

LOCALITIES.—Graham: USNM 513c. Finis: USNM 510. Jacksboro: USNM 512h.

DIAGNOSIS.—Medium-sized, lustrous *Nudauris* with strong costellae and small ears.

TYPES.—Holotype: USNM 148887. Unfigured and measured paratypes: USNM 148889a-c.

COMPARISON.—This species is most like *N. splendens*, new species, from the Gaptank Formation but is smaller, more transversely rectangular and with a more flattened umbonal and visceral region, with more flattened and less pointed ears, less steep lateral slopes, and more narrowly rounded flanks.

DISCUSSION.—This is a very rare species in the Graham Formation but can be readily detected by the lustrous sheen of its shells when well preserved

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 510							
148887	22.9	19.4	40.0	30.0+	30.5	16.4	7.5
(holotype)							
USNM 512h							
148889a	27.4	21.9	50.0	40.0*	35.3	17.6	8.0
148889b	23.2	20.0	42.0+	34.6	31.8	14.0?	7.7
148889c	24.7	20.6	39.0	36.8*	32.0	15.9	8.8



or slightly exfoliated. This species certainly is related to *N. splendens* and helps to emphasize the strong Permian affinities of the Graham Formation.

### *Nudauris reticulata*, new species

PLATE 365: FIGURES 17, 18; PLATE 369: FIGURES 6–20

*Productus semistriatus* R. E. King (not Meek), 1931:74, pl. 15: figs. 6a–c [not figures 7–11].

Medium size for genus, hinge equal to or slightly wider than midwidth, shell body subquadrate, length and width nearly equal. Sides gently rounded and anterior margin broadly rounded. Surface costellate; visceral disc region of both valves neatly and fairly strongly reticulate; concentric undulations strongest on ears and lateral slopes; venter partially reticulate but trail finely costellate, costellae strongest near venter and becoming finer to obsolete anteriorly; costellae numbering five or six per 5 mm near venter. Spines scattered; forming oblique row at posterior margin, terminating in largest spine on ear extremity; halteroid spines scattered on trail. Body spines scattered on visceral disc.

Pedicle valve with unevenly convex lateral profile, venter narrowly rounded, visceral disc region shorter than trail and flatly convex, trail fairly strongly convex. Anterior profile strongly domed with steep sides and slightly indented top. Umbonal region and visceral disc strongly protruding beyond posterior margin in dorsal view. Umbonal and visceral disc regions moderately swollen and narrowed on umbo; umbonal slopes steep. Sulcus originating on visceral disc, narrow but with gentle lateral slopes, continuous to anterior margin but nowhere strongly or deeply impressed. Flanks bounding sulcus moderately inflated. Ears prominent and angular in young but more nearly at right angle in adult and not protruding laterally beyond sides.

Brachial valve deeply concave, with strongly reticulated visceral disc, costellae on trail somewhat stronger than on pedicle valve. Umbonal depression deep, fold low and inconspicuous, originating slightly posterior to midvalve; sides and anterior steep. Ears moderately concave, demarcated by fairly strong, oblique ridge.

Pedicle valve interior with transversely oval and small diductor scars; adductor scars on moderately thickened elongate and narrow ridge, posterior scars strongly dendritic.

Brachial valve interior with moderately long cardinal process having myophore facing dorsally; lateral ridges strong; buttress ridge poorly developed. Brevisseptum reaching greatest height at midvalve, lateral ridges moderately developed; adductor field moderately thickened, outer scars dendritic, inner ones nondendritic. Trail slope strongly and coarsely endospinose.

MEASUREMENTS (in mm).—Thickness of holotype 7.8; of others, unmeasurable.

	length	brach- ial valve length	sur- face length	hinge width	mid- width	height
Moore 9880						
124009a	27.1	18.7	53.0?	36.4	31.0	16.3
124009b	32.1	20.0	61.0?	42.0?*	37.4*	20.9
124009e	22.4	15.1	44.0	26.4*	25.3	14.6
(holotype)						
124009k	22.7	?	44.0	33.3	26.9	15.1
124009l	31.5	?	55.0?	35.3	28.8	18.4
124009m	25.6	?	47.0?	33.2*	26.4	15.9

STRATIGRAPHIC OCCURRENCE.—Camp Creek Formation, Red Eagle Formation, Hueco Formation.

LOCALITIES.—Camp Creek: Moore locality 9880. Red Eagle: USNM 761. Hueco: USNM 728d.

DIAGNOSIS.—Medium-sized *Nudauris* with well-reticulated visceral disc, strong costellae, and gentle median sulcus.

TYPES.—Holotype: USNM 124009e. Figured paratypes: YPM 10667 and USNM 124009a, f, j; 148905a. Measured paratypes: USNM 124009a, b, k–m. Unfigured paratypes: USNM 124009b–e, g–m.

COMPARISONS.—*Nudauris reticulata* is one of the forms referred by authors to *Productus semistriatus* Meek but it differs from that species in having the width much greater, costellae on most of the trail, a less pointed umbo, and a more curved visceral disc region. The sulcus of the Texas species is stronger and more persistent than that of *P. semistriatus* as seen on the illustration of its type (pl. 476: figs. 32–35).

*Nudauris splendens*, new species, is much more deeply sulcate than any of the other species referred to *Nudauris* and thus presents a different appearance.

*Nudauris reticulata* resembles *Productus bathykolpos* Schellwien from the Lower Permian of the Carnic Alps; but that species attains a larger size, has a deeper sulcus, and a more flattened visceral disc region.



*Nudauris splendens*, new species

PLATE 370: FIGURES 1-21

*Productus semistriatus* R. E. King (part, not Meek), 1931:74, pl. 15: figs. 8a-c.

Medium size for genus, subquadrate in outline, hinge forming widest part; sides gently rounded; anterior margin broadly rounded and strongly indented medially; shell lustrous when fresh; deeply concavo-convex. Ears large, subangular to bluntly rounded. Surface unevenly costellate, costellae strongest on visceral disc and venter, usually becoming fine or obsolescent on trail. Costellae numbering five to six on trail near venter. Umbonal slopes and adjacent posterior margins marked by concentric rugae; spines sparsely scattered; in oblique row along posterior margin, final and largest spine occupying extremity of ear; halteroid spines on trail slope. Body spines rare.

Pedicle valve unevenly convex, most curvature on venter, umbonal and visceral regions moderately convex, trail fairly strongly convex and longer than visceral region. Anterior profile high, steep-sided dome moderately to deeply indented medially.

Umbonal and visceral regions moderately inflated and with steep slopes to ears. Sulcus originating on anterior side of umbonal region, moderately to strongly deep and deepening to deeply indented anterior margin. Flanks strongly and narrowly rounded. Umbonal region slightly extended posterior to posterior margin.

Brachial valve deeply concave, deepest somewhat anterior to midvalve; sides and anterior steep. Ears not deeply concave, demarcated by broad, oblique fold. Visceral disc region obscurely reticulate. Fold low, originating on anterior side of umbonal pit.

Pedicle valve interior with large, elongate, and strongly thickened adductor field, posterior scars dendritic, anterior scars narrow, elongate, and smooth. Diductor scars small, transversely oval.

Brachial valve interior with large, stout cardinal process having high, keeled lophidium and moderately developed posterior platform. Lateral ridges strong. Median buttress ridge of cardinal process variable, ranging from nonexistent to strong; adductor field moderately thickened, outer scars dendritic, inner scars smooth. Brachial ridges short but with broad loop.

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 701e							
152745	30.0	?	48.0	40.4	34.8	16.0	?
USNM 701							
148872a	29.1	24.8	58.0	45.0	34.8	20.9	10.2
(holotype)							
148872b	30.4	23.2	60.0	43.0*	36.5	21.3	9.8
148872c	27.6	23.2	50.0	42.0*	36.3	19.5	7.7
148872d	27.5	22.0	49.0?	38.2	32.7	17.0	7.0
148872e	26.0	21.0	49.5	38.8*	35.0	17.3	?
148872f	25.4	21.8	43.0	37.0*	34.6	15.0	6.5
148872g	24.4	20.7	39.0?	32.2*	29.2	14.3	?
148872h	28.5	23.3	52.0	39.1	34.3	18.6	7.9
148872i	27.5	22.5	?	43.2	34.7	19.0	8.6

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member), Neal Ranch Formation, Lenox Hills Formation.

LOCALITIES.—Gaptank: USNM 701y, 730n. *Uddenites*: 701e, 701f, 701p, 701v, 701x, 702n, 705h, 705v. Neal Ranch: 701, 701a<sup>3</sup>, 701c, 706x, 713k. Lenox Hills: 707j, 707o.

DIAGNOSIS.—Transverse *Nudauris* with large ears and a deep median sulcus.

TYPES.—Holotype: USNM 148872a. Figured paratypes: USNM 148872b, k, l. Measured paratypes: USNM 148872b-i, 152745. Unfigured paratypes: USNM 148872c-j, 152745.

COMPARISON.—This species is the most distinctive

one assigned to *Nudauris* because of the comparatively greater depth of its sulcus, causing the flanks to be more narrowly rounded than usual in this genus. None of the species from the Glass Mountains or elsewhere except north-central Texas can be confused with this one. *Nudauris splendens* appears to be related to *N. presplendens*, new species, which occurs in the Graham Formation of north-central Texas. This species is, however, smaller, differently shaped, and less inflated than the Glass Mountains species.

DISCUSSION.—Unsilicified specimens of this species that are cracked out of the rock usually become exfoliated, revealing a shell that is highly glossy, making recognition easy. *Nudauris presplendens* from the Pennsylvanian shales of north-central Texas has the same feature.

### *Nudauris transversa*, new species

PLATE 366: FIGURES 4–22

Medium-sized for genus, slightly wider than long, maximum width at hinge; sides obliquely rounded; anterior margin broadly rounded and medially indented. Surface costellate, with about seven costellae per 5 mm on median part of trail; occasional costae anterior to spine bases on trail; visceral disc moderately reticulated; ears and umbonal slopes with sharp concentric wrinkles. Large halteroid spines, largest at least 20 mm long, arranged in row along posterior margin; trail spines few, scattered, about 15 mm in length.

Pedicle valve with maximum curvature, in lateral view, in posterior half, umbonal region surface and trail surface nearly parallel. Umbonal region inflated, protruding strongly posterior to hinge; median region inflated; trail convex and swollen; sulcus narrow and shallow, originating on anterior side of visceral disc and extending to anterior margin; flanks rounded, with steep, convex sides. Ears narrow and extended, rounded and convex.

Brachial valve deeply concave, maximum concavity in troughs at base of anterior slope; umbonal region deeply depressed; ears depressed slightly concave; lateral and anterior slopes steep; median fold low, obscure, developed best at midvalve and on trail; angle of geniculation about 70°.

Pedicle valve interior without ear baffles and with moderately thickened narrow adductor track.

Brachial valve interior with cardinal process

moderately large and with infolded median lobe and short shaft; lateral ridge short, narrow; brevisseptum slender, anteriorly elevated; anterior slope with short stout endospines.

MEASUREMENTS (in mm).—Thickness of holotype 8.2; of others, unmeasurable.

	length	brach- ial valve length	sur- face length	mid- width	hinge width	height
USNM 725z						
152746a	30.2	?	58.0	31.7	41.8	18.3
152746b	22.8	17.6	45.0	29.9	34.6+	16.0
(holotype)						
152746c	22.8	?	46.0	30.3	34.4	15.6
152746d	23.2	?	43.0	28.2	32.8	14.6
152746e	26.7	?	55.0	30.3	38.0	17.8

STRATIGRAPHIC OCCURRENCE.—Hueco Canyon Formation (just above Powow Conglomerate).

LOCALITY.—USNM 499b = 725z.

DIAGNOSIS.—Medium, thin-shelled *Nudauris*, finely costellate, with narrowly extended ears and a broad gentle sulcus on the pedicle valve.

TYPES.—Holotype: USNM 152746b. Figured paratypes: USNM 152746a, d; 153981a, c. Measured paratypes: USNM 152746a, c-e. Unfigured paratypes: USNM 153746c, e; 153981b.

COMPARISON.—This species is suggestive of *N. reticulata*, new species, but the costellae are finer, the reticulation less, and the umbonal and visceral regions fuller. It differs from *N. splendens*, new species, in its smaller size, less sharp sulcus, finer costellae, thin pointed ears, and in having a less tightly coiled shell when seen in lateral view.

DISCUSSION.—A few silicified specimens of this species were obtained from USNM 725z; they are not very well preserved, but they do show the spines, and are important for that reason. The spines of the posterior are nearly an inch (25 mm) long and extend from the posterior margin at a high angle to the hinge. They, undoubtedly, served as steadying spines. The trail spines are also well preserved and long, but not as long as the posterior marginal spines. The trail spines are broadly curved toward the anterior shell margin.

### *Nudauris tribulosa*, new species

PLATE 367: FIGURES 7–18

Medium size for genus, transversely rectangular in outline, hinge extended into prominent rounded

ears. Sides sloping medially and gently rounded; anterior margin broadly rounded and slightly indented. Beak small, umbonal region not extending far posterior to posterior margin. Surface costellate, costellae subdued; visceral region reticulated. Halteroid spines forming single row along posterior margin and descending slightly onto ears where largest spine is located. Lateral slopes and trail provided with long halteroid spines measuring up to 1.5 inches (37 mm).

Pedicle valve unevenly convex in lateral profile, visceral region gently swollen and gently convex, geniculated area narrowly rounded and trail gently convex; anterior profile strongly domed, with mid-

dle only slightly indented. Sulcus shallow and narrow, extending from visceral region to front margin, there producing slight indentation. Flanks gently rounded.

Brachial valve deeply concave, most concave anteromedially, and with anterior and lateral slopes very steep. Ears demarcated by rounded ridge. Fold low and inconspicuous. Ears strongly concave.

Pedicle valve interior with slightly thickened adductor track. Brachial valve with low and stout cardinal process and slender lateral ridges. Breviseptum low and thin. Brachial ridges moderately developed; anterior and lateral slopes covered by small endospines.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 727e							
152747a	22.8	16.5	45.0	34.7	26.8	15.5	5.9
152747b	22.4	17.7	44.0	33.9	27.8	15.3	6.2
152747c	25.0	19.3	51.0	37.0	31.8	18.0	8.2
(holotype)							
152747d	24.5	16.5	52.0	31.3	28.0	15.8	7.9

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member); Neal Ranch Formation.

LOCALITIES.—*Uddenites*: USNM 701e, 701p? Ranch: 701a<sup>1</sup>; 702t, 706x, 727e.

DIAGNOSIS.—Strongly spiny *Nudauris* with shallow median sulcus.

TYPES.—Holotype: USNM 152747c. Figured paratypes: USNM 152747a,e,f. Measured paratypes: USNM 152747a,b,d. Unfigured paratypes: USNM 152747b,d.

COMPARISON.—This species suggests *N. reticulata*, new species, but differs in having stronger spines, less swollen umbonal region, and less extended ears. It differs from *N. splendens*, new species, in being smaller and in having a much shallower median sulcus.

DISCUSSION.—This is an uncommon species and only a few silicified specimens were available on which to base the description. A few unsilicified specimens are also referred to this species. These have a strongly reticulated visceral disc, as in *N. reticulata*, but are unlike that species in other

respects. The ornament on the silicified specimens is not well preserved, but evidence of strong reticulation can be seen on the visceral disc.

#### *Nudauris whitei*, new species

PLATE 468: FIGURES 29–33

Medium size for genus, transversely rectangular in outline, ears forming widest part. Lateral margins sloping medially, anterior margin broadly rounded. Surface of both valves marked by low, broadly rounded costellae becoming faint on trail but cancellated by undulations of about equal size on visceral disc region and continuing to margin of trail. Brachial valve similarly marked. Spines in row along hinge margin and one prominent spine on each ear; trail with few randomly scattered spines.

Pedicle valve strongly inflated, posterior projecting strongly posterior to hinge. Beak small; ginglymus short and concave. Umbonal region somewhat depressed when seen from dorsal side. Shell strongly swollen when seen from ventral side, with deep, narrow, subangular sulcus dividing pos-

terior into two lobes. Lateral slopes vertical; ears rounded in section strongly depressed below surface of pedicle valve. Interior not known.

Brachial valve deeply concave; ears deflected and marked off by low ridge. Umbonal region deeply concave; fold low and subangular extending from anterior of umbonal depression to anterior margin. Cardinal process with small low lophidium. Interior unknown.

MEASUREMENTS (in mm).—From USNM 738d, specimen 153920a (holotype): length 31.0, brachial valve length 27.1, surface length 57.0, hinge width 43.6, midwidth 40.0, thickness 12.2, height 18.8.

STRATIGRAPHIC OCCURRENCE.—Cibolo Formation (Transition Beds of Udden).

LOCALITY.—USNM 738d.

DIAGNOSIS.—Large *Nudauris* with subdued costae and strongly inflated pedicle valve with deep median sulcus.

TYPES.—Holotype: USNM 153920a. Unfigured paratype: USNM 153920b.

COMPARISON.—This species differs from *N. diabloensis* Stehli, the type species, in being smaller, in having more subdued costae, fewer body spines, and a narrower, more angular sulcus on the pedicle valve. It differs from *N. splendens*, new species, in having stronger ornament, a narrower, more angular sulcus on the pedicle valve, and more rounded ears.

DISCUSSION.—The species is named in honor of Mr. Russel White, owner of Cibolo Ranch on which the specimen was found.

### Genus *Dasysaria* Cooper and Grant, 1969

*Dasysaria* Cooper and Grant, 1969:9.

Large, transversely quadrate Dictyoclostidae with hinge forming widest part. Ears large, prominent, extended. Geniculation moderate. Surface semi-reticulate, reticulation of both valves fine and irregular; trail irregularly but finely costate. Spines numerous; thick tuft of halteroid spines on ears and posterior margin; fine body spines most abundant on visceral disc, scattered on costae of trail. No spines on brachial valve.

Pedicle valve interior with moderately thickened elongate adductor field; scars dendritic. Diductor scars widely flabellate.

Brachial valve interior with widely trilobate, typically dictyoclostid cardinal process; lateral ridges strong; brevisseptum strong; adductor field not greatly thickened but strongly dendritic. Brachial ridges strongly developed. Anterior slope with small endospines.

TYPE-SPECIES.—*Dasysaria undulata* Cooper and Grant (1969:9, pl. 5: figs. 32–34).

DIAGNOSIS.—Similar to *Squamaria* Muir-Wood and Cooper but lacks dorsal spines and is usually more finely ornamented.

COMPARISONS.—The above diagnosis defines the most obvious difference between *Dasysaria* and its nearest relative *Squamaria*. This is not, however, the only distinction between the two genera. The ornament of *Dasysaria* is as distinctive as the lack of spines on the brachial valve.

The visceral discs of both valves are reticulate, as is true of many of the dictyoclostids, but the dasysariid reticulation is distinctive. Concentric undulations are strong but irregular, strongest laterally along the posterior margin and lateral slopes but also strong over the visceral disc. The costellae are usually fairly fine and cross the undulations without being interrupted by them. The costellae are as strongly elevated in the troughs of the undulations as they are on their crests. This does not produce the strongly cancellated effect of *Reticulatia*, in which the costellae are interrupted. The costellae of *Dasysaria* undulate over the concentric rugae, producing a type of visceral disc quite different from that in other dictyoclostids.

*Dasysaria* is also like *Peniculauris* Muir-Wood and Cooper, which occurs higher in the Leonardian. That genus is always sulcate, whereas a sulcus in the pedicle valve of *Dasysaria* is rare, and the pedicle valve is more strongly swollen than that of *Peniculauris*. Furthermore, the ornament of *Dasysaria* is finer than that of *Peniculauris*. It is possible that *Dasysaria* is the direct ancestor of *Peniculauris*.

DISCUSSION.—This genus is characteristic of the Wolfcampian series of the Permian and occurs in many types of facies from Texas north to Kansas. *Dictyoclostus welleri* (R. H. King, 1938) is placed here as well as *Productus wolfcampensis* (R. E. King). In Kansas this genus is common in several formations. *Productus calhounianus* Swallow, a poorly known species (Boos, 1929) belongs here.

*Dasysaria undulata* Cooper and Grant

PLATE 363: FIGURES 1-7; PLATE 364: FIGURES 1-17

*Productus hessensis* R. E. King, 1931:68, pl. 11: figs. 3, 4 [not 5 and 6].  
*Productus wolfcampensis* R. E. King, 1931:74 (part), pl. 16: figs. 4, ?5.  
*Dasysaria undulata* Cooper and Grant, 1969:9, pl. 5: figs. 32-34.

Large, length and midwidth about equal, somewhat square in outline, hinge forming widest part; ears large, extended. Sides gently rounded; anterior margin broadly rounded. Surface semirectulate, visceral disc of both valves marked by closely spaced undulations crossed by strong costellae; trails of both valves marked by costellae of unequal size, larger costellae alternating with one or two smaller ones, six to seven costellae per 10 mm. Halteroid spines slender, forming tuft on ears. Thin and delicate body spines abundant on trail, costellae, and visceral disc.

Pedicle valve strongly and fairly evenly convex in lateral profile, maximum convexity near midvalve; anterior profile broad, dome with precipitous sides. Umbonal region fairly strongly inflated and protruding considerably posterior to posterior margin. Sulcus shallow when present, usually poorly defined, originating on visceral disc but strongest on trail. Flanks bounding sulcus slightly swollen.

Brachial valve broadly geniculated and deeply concave, most concavity in anterolateral regions. Fold low and inconspicuous. Ears not conspicuous, demarcated by low ridge.

Pedicle valve interior with broadly flabellate diductors and moderately thickened adductor tracts.

Brachial valve interior with wide, stout cardinal process on posterior platform and supported by secondary median ridge joining brevisseptum. Lateral ridges moderately developed. Adductor field strongly dendritic but not greatly thickened. Brachial ridges well developed.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 719							
148917a	47.3	?	95.0	?	46.5	27.3	?
148917b	48.4	?	95.0	?	46.3	26.8	?
148917c	38.3	?	74.0	51.6*	40.4	23.4	?
148917d	40.0	?	89.0	56.6*	43.6	28.8?	?
USNM 720c							
148916a	48.8	36.3	92.0	50.0*	49.0	33.5?	23.4
AMNH 626							
148919a	41.0	30.8	70.0	46.0	39.0	23.5	17.8
USNM 720a							
148914 (holotype)	42.5	32.0*	73.0	41.0	44.5	33.5	?

STRATIGRAPHIC OCCURRENCE.—Hueco Canyon Formation, Bone Spring Formation.

LOCALITIES.—Hueco Canyon: AMNH 626; USNM 719, 720a, 720c, 728d. Bone Spring: AMNH 697.

DIAGNOSIS.—Large *Dasysaria* with strong costellae and strongly reticulate visceral disc, squarish body, and moderate-sized ears.

TYPES.—Holotype: USNM 148914 = 153880. Figured hypotypes: USNM 148916; 148918b;

148919a; 153879a, b, d. Measured hypotypes: USNM 148916a, 148917a-d, 148919a.

COMPARISONS.—This species is related to *D. wolfcampensis* (R. E. King) in its general appearance but it is a much larger species, with stronger costellae and reticulation. It is also less extended posterior to the hinge than *D. wolfcampensis* when viewed from the dorsal side.

*D. undulata* also strongly suggests *D. welleri* (R. H. King) and attains approximately the same size



but differs in details as follows: the ears are more extended; the ornament is somewhat stronger, although this is variable in both species; the contours are less rounded, the body is squarer, and the brachial valve less concave.

DISCUSSION.—This species has been confused with "*Productus*" *hessensis* R. E. King, the type specimen of which proves to belong to *Antiquatonia* Miloradovitch. At least two species are included in R. E. King's type lot of "*P.*" *hessensis* and the type specimen is incompletely figured. Because the visceral disc area of the pedicle valve is not clearly shown generic assignment is difficult. *Dasysaria undulata* is common in parts of the Hueco Canyon Formation, especially on Threemile Mountain northwest of Van Horn, Texas.

### *Dasysaria welleri* (R. H. King)

PLATE 363: FIGURES 8–15

*Dictyoclostus welleri* R. H. King, 1938:273, pl. 39, figs. 5–8.

Hypotypes USNM 148926a, b, and 148927a of this species are illustrated here for comparison with other species of *Dasysaria*.

STRATIGRAPHIC OCCURRENCE AND LOCALITY.—Putnam Formation. 0.1 mile south of U.S. 80, 2.3 miles west of Putnam, Callahan County, Texas.

TYPES.—Figured specimens: USNM 148926a, b; 148927a.

### *Dasysaria wolfcampensis* (R. E. King)

PLATE 365: FIGURES 1–16

*Productus wolfcampensis* R. E. King, 1931:74, pl. 16: figs. 1–3 [not figs. 4, 5].

Small for genus, length and midwidth about equal; hinge forming widest part; ears moderately large and extended. Sides rounded; anterior margin broadly rounded. Surface semireticulate, visceral disc of both valves marked by costellae, interrupted by fine, somewhat wavy undulations to form fine and irregular pattern. Trail costellate, costellae numbering four or five per 5 mm and usually variable in size and frequently grouped into longitudinal undulations. Halteroid spines in bundle on ears; small body spines scattered on visceral disc and trail.

Pedicle valve with unevenly convex lateral profile, posterior half having greater convexity; anterior profile forming high-rounded, steep-sided dome. Umbonal region moderately swollen and ex-

tended considerably posterior to hinge. Median region strongly swollen; sulcus variable, from absent to moderately developed, when present, originating on visceral disc and extending to anterior margin, usually not well developed. Flanks well rounded.

Brachial valve strongly geniculated, deepest at place of geniculation, with steep lateral and anterior slopes. Visceral disc region strongly reticulated and fairly deeply concave; fold poorly developed, if at all.

Pedicle valve interior with slightly thickened, elongate adductor field. Brachial valve with strong lateral ridges and posterior platform supporting cardinal process; brevisseptum strong, connected with cardinal process by low rounded thickening to form continuous ridge. Cardinal process small and variable.

MEASUREMENTS (in mm).—Thickness of USNM 148921b is 17.8; of others, unmeasurable.

	length	brach- ial valve length	sur- face length	hinge width	mid- width	height
USNM 725z						
148921a	35.0	?	75.0	42.6*	39.0	22.0
148921b	39.5	26.7	93.0	50.8*	40.4	27.3
148921c	40.8	?	80.0	41.0+	40.3	21.7
USNM 704r						
148923	35.8	25.8?	65.0?	37.0	31.6	19.0+

STRATIGRAPHIC OCCURRENCE.—Hueco Canyon Formation, Lenox Hills Formation.

LOCALITIES.—Hueco Canyon: USNM 499b = 725z. Lenox Hills: 704r.

DIAGNOSIS.—Small and narrow *Dasysaria* with length and midwidth nearly equal.

TYPES.—Holotype: T10339. Figured paratypes: YPM 10343, 10663. Figured hypotypes: USNM 123991a, b; 148921a-d. Measured hypotypes: USNM 148921a-c, 148923.

COMPARISON.—See *D. undulata* Cooper and Grant.

DISCUSSION.—In the Glass Mountains this is a very rare species. We have found only three specimens in the Lenox Hills Formation.

### Genus *Rugatia* Muir-Wood and Cooper, 1960

*Rugatia* Muir-Wood and Cooper, 1960:285.—Williams et al., 1965:H497.

Large, dictyoclostid in appearance, generally slightly wider than long; body subrectangular to

subquadrate; hinge usually wider than midwidth; ears large and prominent; pedicle valve fairly strongly sulcate; strongly concavo-convex. Surface with visceral disc region crudely reticulated; venter and trail unevenly costate, costae narrowly rounded. Spines of pedicle valve thick, halteroid, tuft of long spines concentrated on ears and occasionally on trail slope; body spines distantly scattered, usually short and curved toward anterior. Brachial valve ornamented like that of pedicle valve but without spines.

Pedicle valve with deeply concave ears without baffles; diductor scars flabellate; adductor field elongate and elevated on thick platform; posterior and inner anterior scars strongly dendritic; region anterior to visceral disc strongly granulose.

Brachial valve with small cardinal process on posterior platform in adults; process bilobed in ventral view in young and in young adults but widely trilobed in old specimens. Myophore trilobed in dorsal view and with prominent roughened median lobe. Lateral ridges short, extending laterally from cardinal process but disappearing before reaching ears; no ear baffles, ears strongly convex on inside. Brevisseptum short, low proximally but abruptly rising to crest at distal end. Brachial ridges extending directly laterally, narrowly looped at edge of visceral disc. Adductor field large, rhomboid, consisting of two thick triangular platforms with apices directed laterally, entire surface strongly dendritic; posterior part of trail slope on edge of visceral disc, minutely endospinose.

TYPE-SPECIES.—*Productus (Dictyoclostus) paraindicus* McKee (1938: 241, pl. 46: figs. 5a, b).

DIAGNOSIS.—Crudely reticulate and irregularly costate Dictyoclostidae with a tuft of large, thick, halteroid spines on the ears and a few scattered on the trail slope.

COMPARISONS.—*Rugatia*, with its irregularly costate trail and poorly reticulate visceral disc, is readily recognized as a member of the Dictyoclostidae and this is confirmed by the characteristic cardinal process. In external appearance it suggests the Salt Range genus *Costiferina* Muir-Wood and Cooper, from which it differs in lacking the strong ear baffles and large posterior platform in the brachial valve. The spine arrangement of the two genera is likewise different. The general configuration and ornament are quite different from most other dictyoclostid genera. Some species of *An-*

*tiquatonia* have the form and large ears of *Rugatia* but these usually have a spine-bearing ridge on the lateral slope over the ears or a row of spines in this position. The spine row of *Rugatia* is not on the lateral slope but is just anterior to the posterior margin and runs on to the ear. In *Antiquatonia* the ears themselves lack spines. The same distinction separates large specimens of *Liosotella* Cooper and *Paucispinifera* Muir-Wood and Cooper, which have spineless ears.

DISCUSSION.—Externally the members of this genus are deeply concave and the pedicle valve is strongly enrolled, the umbonal and visceral disc regions being visible from the dorsal side. Old specimens have a length almost equal to the width, although the hinge is usually extended considerably beyond midlength on both sides of the valve. The ears are strongly rounded and prominent, protruding conspicuously on both sides of the valve.

The ornament of this genus is distinctive, as it consists of a crudely reticulate visceral disc region in both valves and large, fairly thick but irregularly developed costae. On the brachial valve the costae are best developed on the anterior half of the valve or trail. The genus is likewise sparsely spinose.

The most prominent spines are concentrated on the ears although large spines appear elsewhere. The main halteroid spines are concentrated on the ears but some appear also scattered on the lateral slopes, and around the anterior margin on the trail slope. Five to seven spines usually appear on the ear, but in many specimens smaller spines occur between this tuft and the umbonal slope. The ear spines reach a length of 66 mm (2.5 inches) and a diameter of 2.5 mm. No definite direction was noted in which these spines extended laterally. Some curve anterolaterally but many extend ventrolaterally.

In addition to the large ear spines, halteroid spines of considerable length and diameter appear around the anterior margin and in an anterior position on the trail slope. The body spines are generally short, less than 1 mm in diameter, and curve anteriorly. They arise from the costae and leave small rounded bases.

The adductor platform is the most conspicuous feature of the pedicle valve interior. This is enormously thick in most specimens but one (USNM 149521) is actually excavated anteriorly. Individual

muscle marks are not easily discerned because all of them are dendritic. In the holotype the posterior scars are longitudinally marked, whereas the anterior ones have a more intricate and more compact pattern. The posterior margin on each side of the beak is thickened and articulates with the sloping faces of the posterior platform.

Inside the brachial valve the cardinal process is a conspicuous feature and is usually variable. It surmounts a posterior platform that is made up of the medially united lateral ridges. These are short and die out laterally on the posterior margin before reaching the ears. The dorsal concave slope of the posterior platform on each side of the cardinal process helps to articulate the valves, receiving the thickened area on each side of the beak of the pedicle valve.

In young adults the cardinal process is generally narrow and bears a depression on the posteromedian surface which extends onto the median lobe. The lateral lobes in young adults are subparallel, usually thin, and overhang the median lobe, which is elongate and has a transversely roughened surface. In old specimens the cardinal process becomes widely trilobed, with the lateral lobes widely divergent and the median lobe thickened and itself bilobed. Surfaces of all the lobes are greatly roughened. The cardinal process is buttressed in many specimens by a low rounded ridge that extends anteriorly to meet the proximal end of the brevisseptum.

The adductor field of the brachial valve, like that of the opposite valve, is completely dendritic. It is commonly greatly thickened and is crudely rhombic in outline, the scars on each side of the septum forming a triangle with its apex directed laterally. Anterior and posterior scars are distinguishable only with difficulty. The position of the brachial ridge is helpful in locating the anterior adductor set.

The brevisseptum is generally low proximally but rises abruptly to a crest at the anterior end and generally does not quite reach midvalve. In one obese specimen (USNM 149521) the distal end of the brevisseptum bears a thick transverse knob, somewhat suggesting the club-shaped mass on the distal end of the brevisseptum of *Tyloplecta* Muir-Wood and Cooper.

ECOLOGY.—It is interesting to note the conditions under which this genus lived at USNM 702un.

Most of the specimens recovered are heavily covered with bryozoa or perhaps algae. In some the spines are heavily overgrown and in others the animals must have been dead before burial because the front margins have been sealed by bryozoan growth. *Rugatia* at this place lived intimately among numerous branching bryozoans. One large specimen (USNM 149250) was found suspended from bryozoan branches by its long spines. It is suggested that, at this place in Permian time, the long halteroid spines of *Rugatia* suspended their shells among the branches of the forest of bryozoans that grew there.

### *Rugatia convexa*, new species

PLATE 373: FIGURES 1–19

Medium size for genus, with shell body longitudinally rectangular, hinge about equal to length; hinge forming widest part; ears somewhat bulbous, large and rounded; sides gently rounded; anterior margin rounded and indented medially. Umbonal and visceral disc regions obscurely reticulate; venter and trail with subdued, irregular costae. Pedicle valve sparsely spinose; row of halteroid spines just anterior to posterior margin terminating in two large spines, largest on ear extremity; scattered halteroid spines on trail; body or ornament spines widely scattered, erect, on visceral disc, umbonal region, venter, and trail.

Pedicle valve in lateral profile unevenly convex, greatest curvature at venter but visceral disc region fairly strongly convex, trail moderately convex. Anterior profile narrowly and strongly domed, median region indented. Umbonal and visceral regions fairly strongly swollen and steep-sided, extended considerably beyond posterior margin; median region inflated. Sulcus originating on visceral disc region, deepest on midtrail, and flattening and shallowing at anterior margin. Flanks rounded and with precipitous sides.

Brachial valve moderately deep; umbonal pit large; ears shallow and not strongly demarcated, marked by rugae and dimples representing spines of opposite valve. Sides and anterior steep; fold low, originating just posterior to midvalve, not strongly defined.

Pedicle valve interior with moderately thickened adductor platform, small diductor scars, and minutely granulated anterior trail surface and sides.

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702c							
149530a	36.1	?	67.0	38.6	32.3	23.4	?
149530b	25.8	20.7	47.0	37.4	30.5	14.9	6.2
149530c	33.2	22.2	72.0	42.6	35.0	23.3	15.0
149530d (holotype)	28.9	21.0	52.0	43.6	32.0	17.5	10.5

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITY.—USNM 702c.

DIAGNOSIS.—Medium-sized *Rugatia* having subdued reticulation and costae and strongly rounded contours.

TYPES.—Holotype: USNM 149530d. Figured paratypes: USNM 149530a, b, e. Measured paratypes: USNM 149530a-c. Unfigured paratypes: USNM 149530c.

COMPARISONS.—The subdued character of the ornament of this species allies it to *R. paraindica* (McKee). The latter attains a much larger size than *R. convexa*, has more ponderous ears and differently arranged halteroid spines on the posterior side of the shell. In the Grand Canyon species, the posterior halteroid spines form a tuft on the ears. Although a row of small spines can be seen arranged on the anterior side of the posterior margin in McKee's species, it develops a number of spines that are clustered on the ears. In the Glass Mountains species, the spines appear in an oblique row on the anterior side of the posterior margin and increase in size to the ears, where the last and next to last spines in the row are large and also extend directly laterally. Furthermore, the visceral disc and umbonal regions of *R. convexa* seem to be more abundantly adorned with short body or ornament spines. *Rugatia convexa* is an uncommon species; only five specimens were obtained out of the numerous blocks etched from USNM 702c.

*Rugatia incurvata* (R. E. King)

PLATE 377: FIGURES 1-46

*Avonia incurvata* R.E. King, 1931:83, pl. 20: fig. 6.

Small for genus, wider than long, outline sub-

rectangular; hinge forming widest part; cardinal extremities usually extended into acute ears. Sides oblique; anterior margin broadly rounded but median part slightly indented. Surface irregularly and softly costate; ears with concentric wrinkles which extend to venter, there reticulated by costae. Spines few, halteroid, stout, row descending from beak along base of umbonal slope onto anterior side of ear but leaving tip of ear free; moderately long anteriorly curved spines scattered on venter and longer curved spines on trail. No spines on brachial valve, but dimples corresponding to spines of pedicle valve; ears with prominent concentric undulations.

Pedicle valve strongly but unevenly convex in lateral profile, maximum curvature at venter; anterior profile somewhat squarely domed, sides nearly straight, crest of dome flattened or medially depressed. Beak small; umbonal region broadly inflated and extending considerably posterior to posterior margin. Median region swollen. Sulcus shallow, originating on umbonal region and extending to anterior margin, uniformly narrow and shallow. Ears depressed, rounded and narrow. Anterior slope steep.

Brachial valve forming isosceles trapezoid with hinge forming widest part; moderately concave, greatest concavity at base of trail; sides sloping steeply inward; ears prominent, slightly concave.

Pedicle valve interior without ear baffles and with thickened adductor field, especially in old specimens.

Brachial valve with stout but short-shafted cardinal process with median lobe incurved and lateral lobes narrow. Adductor field moderately thickened, posterior scars lying posterior and lateral to anterior pair; brevisseptum small; brachial ridges short and narrow.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
King 46							
YPM 11583	16.0	10.2	34.0	17.9	22.7	10.5	7.5
(holotype)							
USNM 702c							
152751a	14.0	9.8	30.0	17.0	21.5	9.0	6.1
152751b	11.7	8.9	22.0	15.1	16.4	6.9	4.3
152751c	14.6	8.7	?	16.0	17.7	10.5?	5.6
USNM 703a							
152752	12.7	?	27.0	16.7	19.5	7.6	?

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation (base).

LOCALITIES.—R. E. King 46; USNM 702c, 703, 703a, 703c, 703d, 719x, 724b.

DIAGNOSIS.—Small *Rugatia* with long, stout, scattered spines and moderately reticulated venter.

TYPES.—Holotype: YPM 11583. Figured hypotypes: USNM 152751a, c, d; 154005a, b, d, e, g; 154006a-c; 154007. Measured hypotypes: USNM 152751a-c, 152752.

COMPARISON.—The small size of this species is its most conspicuous character. It is placed in *Rugatia* because of the similarity of the ornament, the spine arrangement, and interior features to other species of the genus. Differences are in the stronger reticulation on the venter, not well preserved in all specimens, the relatively longer body spines, and the less deep sulcus on the pedicle valve. Inside the brachial valve the adductor scars are not so intricately dendritic as in larger species.

DISCUSSION.—The young of this species have flattish valves and the spines are disproportionately long for the shell body. A specimen 4.5 mm long has one body spine 9 mm long. These early spines on the body are strongly curved and must have helped to keep the body above the bottom by entangling with other objects or perhaps supported by the tips of the spines with the shell dorsal side down.

Thickening of the interior parts is exaggerated in old shells. The adductor field of the pedicle valve is enormously thickened in one old adult from USNM 702c. The cardinal process and adductor field of the brachial valve are likewise greatly thickened with age. The brachial ridges are not greatly affected.

*Rugatia mckeei*, new species

PLATE 376: FIGURES 1–14

*Productus indicus* King (part, not Waagen), 1931:72, pl. 13: figs. 6, 8, 9.

Large, transversely elliptical in outline, hinge forming widest part; shell body rectangular; ears large, prominent, rounded, dominating lateral regions. Sides short, oblique, nearly straight; anterior margin broadly rounded. Surface strongly costate; visceral disc region of both valves strongly reticulate, ornament being carried onto ears; venter and trail marked by strong, boldly elevated costae separated by interspaces about as wide as costae; trail of brachial valve strongly costate. Pedicle valve sparsely spinose; row of large halteroid spines along posterior margin, largest on extremity of ear; few large halteroid spines on trail slope, especially near margin; smaller, scattered, and inconspicuous body spines.

Pedicle valve unevenly convex in lateral profile, venter narrowly rounded, umbonal region somewhat flattened, and trail moderately convex; anterior profile two-tiered dome, ears forming low tier surmounted by median steep-sided dome with wide, deep median depression. Umbonal and visceral regions moderately swollen, protruding moderately posterior to posterior margin, and with steep umbonal slopes; median region inflated. Sulcus originating on umbo, deep and wide, extending to moderately indented anterior margin. Flanks narrowly rounded and with steep sides. Ears strongly rounded, costate, in old specimens occupying most of lateral region.

Brachial valve deeply concave; umbonal region broadly depressed; sides and anterior, steep and



strongly costate; ears well-demarcated, deeply concave, costate, and dimpled, and with concentric rugae. Fold originating at anterior end of umbonal depression, low, carinate, not strongly defined.

Pedicle valve interior with small, striated diductor scars and elongate, elevated adductor platform with longitudinally dendritic posterior scars; anterior scars closely dendritic.

Brachial valve interior with moderately developed posterior platform, strong angular lateral ridges and large brachial ridges. Cardinal process large, trilobed; adductor field wholly dendritic, moderately thickened, mostly at lateral angles. Brevisseptum forming plate attached to valve floor at distal end.

**MEASUREMENTS** (in mm).—From locality USNM 707e, specimens 149535a and 149534b (holotype), respectively: length 38.2, 41.0; brachial valve length 21.0, 25.6; surface length 78.0, 84.0; hinge width 57.6, 60.3; midwidth 44.9, 45.0; height 26.4, 28.5; thickness 12.9, 19.3.

**STRATIGRAPHIC OCCURRENCE**.—Road Canyon Formation.

**LOCALITIES**.—AMNH 503; USNM 703c, 703d, 707e, 735a.

**DIAGNOSIS**.—Large *Rugatia* with strongly reticulate visceral disc region on both valves, strong costae on trail, and a deep, wide sulcus.

**TYPES**.—Holotype: USNM 149534b. Figured paratypes: USNM 149534a, 149535a, 154001. Measured paratypes: USNM 149535a. Unfigured paratype: USNM 149534c-g, 149535.

**COMPARISONS**.—This species gives the appearance of greater width than length when viewed from the dorsal side. It is readily recognized by the more positive character of the ornament, the strong reticulation in the visceral region, and the greater strength of the costae of the trail and venter. In these respects it differs from *R. paraindica* (McKee) and *R. convexa*, new species, both of which have more subdued ornament. It is the largest species of this genus found in the Glass Mountains.

McKee (1938: 241) referred King's *Productus indicus* to his species *P. paraindicus*, which was made the type of *Rugatia* by Muir-Wood and Cooper (1960). These authors identified the large upper Leonard specimens, which are fairly common in the Glass Mountains, with McKee's species rather than the Road Canyon specimens. King referred the Leonard specimens to *Productus occidentalis*

Newberry, but that is a much smaller and differently proportioned species.

### *Rugatia occidentalis* (Newberry)

PLATE 378: FIGURES 9–13

*Productus costatus* Marcou (not Sowerby), 1858:46, pl. 5: fig. 5.

*Productus occidentalis* Newberry, 1861:122, pl. 2: figs. 9, 10.—R. E. King, 1931:72, pl. 14: figs. 10?, 11, 12, 14 [not fig. 13, = *Rugatia paraindica* (McKee, 1938)]. [Not of Girty 1909:262, pl. 12: figs. 4, a–c (= *Liosotella* Cooper).]

*Productus* (*Dictyoclostus*) *meridionalis* McKee in Stoyanow, 1936:528.

This species has been widely and well discussed although it is not well illustrated and its interior details have not been described. It is therefore unnecessary to repeat the details of its exterior, but some remarks on the interior are in order to establish its generic affinities with *Rugatia*. The species is generally recognized by its subparallel sides, the extended hinge with conspicuous ears, and paucity of thick spines. In the Glass Mountains specimens, a slightly oblique row of spines adorns the posterior, the last and largest spine located on the ear. Spines are scattered on the venter and trail but several are arranged in a crude row on each side of the shallow sulcus. The ears of the Glass Mountains specimens are narrower and more rounded than typical for *Rugatia*. Although the pedicle valve is elongated and somewhat longitudinally rectangular in outline, the brachial valve is much shorter and is rather transversely rectangular in outline.

Inside the pedicle valve the diductor scars are widely separated by an enormously thick and long adductor platform with dendritic scars. These diductors cover the narrow anterior platform and expand posteriorly and laterally to form a large patch posterior to the adductors. It seems possible to resolve the adductors into four scars, two anterior and two posterior ones. Much of the trail area and that of the flanks is covered by small, short endospines. No baffles restrict the ear channels.

Inside the brachial valve the cardinal process is sessile, trilobed, and typically dictyoclostid in its construction. The lateral ridges are narrow and extend nearly to the ears. The adductor field is small, subcircular, and divided by a thin and delicate brevisseptum. The brachial ridges are well de-

veloped. The trail slope is marked by fine endospines.

TYPE.—Hypotype: USNM 154009.

*Rugatia occidentalis parvaauris*, new subspecies

PLATE 378: FIGURES 1-8

The name *R. occidentalis parvaauris* is suggested for the Glass Mountains species because of its generally smaller size and narrower, more rounded ears than those of the typical species. The holotype (USNM 153471) measures (in mm): length 31.0, brachial valve length (distance from hinge to front margin) 17.8, hinge width 33.0, midwidth 27.4, thickness unmeasurable.

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITIES.—USNM 702, 703a<sup>1</sup>, 711q, 721r, 726y.

DIAGNOSIS.—Elongate, rectangular *Rugatia* with small, thick, rounded ears.

TYPES.—Holotype: USNM 153471. Figured paratypes: USNM 154008a, b.

COMPARISON.—The subspecies is distinguished from the typical species by its thick, narrow, and rounded ears.

DISCUSSION.—*Rugatia occidentalis* is an abundant species in some of the Permian areas in Arizona and Utah but it is not common in the Glass Mountains, although King (1931:73) reports it as abundant at his locality 174. There can be little doubt that the Glass Mountains specimens belong to this

profile broadly domed, with long steeply sloping sides and deeply indented top.

species but it is also clear that they do not conform exactly to the type.

*Rugatia paraindica* (McKee)

PLATE 374: FIGURES 1-19; PLATE 375: FIGURES 1-13

*Productus occidentalis* King (not Newberry), 1931:72, pl. 14: fig. 13 [not 11 and 14].

*Productus (Dictyoclostus) paraindicus* McKee, 1938:241, pl. 46: fig. 5.

*Rugatia paraindica* (McKee) Muir-Wood and Cooper, 1960: 286, pl. 107: figs. 1-13.

Large, length and width nearly equal, body of shell rectangular to quadrate; hinge wide, usually widest part; ears large, narrowly rounded, occupying about half of hinge width; anterior margin broadly rounded. Surface costate, costae irregular, reticulated on visceral disc where crossed by irregular, subdued, concentric rugae; costae on trail strong, irregular, strongest on flanks, subdued on venter. Brachial valve costae strongest on anterior half or trail, posterior half with subdued reticulation or nearly smooth. Pedicle valve sparsely spinose, large halteroid spines concentrated in tuft on ears and posterior margin; spines attaining length of 66 mm and diameter of 2.5 mm; other large halteroid spines scattered on anterior part of trail and lateral slopes. Body spines short, curved, and scattered on shell body and arising from costae.

Pedicle valve having uneven profile, greatest

MEASUREMENTS (in mm).—*Rugatia paraindica* (McKee):

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702un							
123439a	29.3	21.6	58.0	45.0	31.0	19.8	9.1
123439d	43.3	?	87.0	56.7	41.9	29.0	?
123439e	39.0	27.6	72.0	43.0	41.1	24.7	14.9
149521a	36.2	24.6	74.0	49.0	43.0	25.2?	12.6
149521b	35.3	26.4	67.0	49.7	43.2	23.1	12.1
149521c	29.0	21.0	50.0	42.8	34.3	16.6	8.7
159621d	21.9	18.8	37.0	28.0	23.9	11.5	4.8
149521e	18.4	14.0	33.0	26.4	24.1	10.9	5.3
149521f	52.0	28.0	105.0?	57.3?	46.0?	31.6?	18.0?
McKee locality							
102297	35.0?	22.0?	?	45.0	37.7	26.0+	?
(lectotype)							
USNM 702							
123996d	31.3	19.0	62.0	48.0*	35.0	20.8	10.6

curvature at venter, trail gently convex and umbonal or visceral regions gently convex; anterior

Umbonal and visceral regions gently convex and strongly extended beyond posterior margin in dorsal view; median region strongly swollen; sulcus moderately deep, narrow, originating on anterior side of umbonal region and extending to anterior margin, this moderately indented in some specimens, not in others. Flanks somewhat narrowly rounded and sides steep. Ears ponderous, strongly rounded, and, in old shells, occupying half of lateral areas.

Brachial valve deeply concave, deepest at midvalve; umbonal region elongate depression; ears large and deeply concave, demarcated by low oblique ridge bounding visceral area; sides and anterior steep; fold originating slightly posterior to midvalve, low and narrow.

Pedicle valve interior with long, narrow, anteriorly pointed and strongly elevated adductor platform; diductor scars strongly and longitudinally striated; no ear baffles; inner surface of ear, lateral areas, and trail surface strongly granulose.

Brachial valve interior with variable cardinal process, narrow in youth but strongly trilobed in old age; posterior platform large and elevated; buttress ridges of cardinal process evanescent; brevisseptum slender and high-crested distally; adductor field dendritic, large, and thick; brachial ridges moderately developed; trail slope minutely endospinose.

STRATIGRAPHIC OCCURRENCE.—Bone Spring, Cathedral Mountain, and Road Canyon formations.

LOCALITIES.—Bone Spring: AMNH 369. Cathedral Mountain: AMNH 500C, 500X, 504; USNM 700-1, 702, 702a, 702b, 702 low, 702un, 703a<sup>1</sup>, 703b, 708, 711q, 714v, 721u, 724r, 726o, 726u, 726y, 731b, 732u, 733m, 735b, 735g, 735i. Road Canyon: USNM 703a, 721r, 721y, 723x.

DIAGNOSIS.—*Rugatia* of large size having poorly reticulate visceral disc region, irregularly costate trail, and a thick tuft of halteroid spines on the ears.

TYPES.—Lectotype (Muir-Wood and Cooper, 1960:286): USNM 102297. Paratypes: 102298a-c. Figured hypotypes: 123438e; 123439a, b, c, f; 123996a, d; 149515; 149520; 149521a-f; 154002a, c; 154003; 154004. Measured hypotypes: USNM 123439a, d, e; 123996d; 149521a-f.

COMPARISONS.—This species is readily distinguished from the others described from the Glass Mountains by the thick brush of spines concentrated

on the ears. In the character of its costae it is intermediate between *R. convexa* and *R. mckeei*, both new species, being more subdued than the latter but stronger in all respects than the former.

DISCUSSION.—McKee's type specimens consisted of four cotypes, of which Muir-Wood and Cooper chose the figured one (USNM 102297) as lectotype. The proportions and costae of the Grand Canyon specimens are very close to those of the Glass Mountains now referred to this species, but the spine arrangement is not clear. Only the lectotype preserves both ears and it is not possible to see bases or scars of all the spines. That a row of spines occurred on the anterior side of the posterior margin is clear, but it is not certain how many spines occupied the ears. The smooth specimen in the type lot referred to by Muir-Wood and Cooper is a brachial valve interior of somewhat dubious identity. It shows a few costae but does have traces of the brachial ridges. The cardinal process is broken and the other interior features, except the granules on the trail slope, have been eroded away.

Although a fair number of specimens of this species was taken from the Glass Mountains, few of the young were found. These are slightly wider than long, of gentle convexity, and with indistinct ornament. The earliest stages of the species are unknown.

Two specimens from AMNH 369 are placed here but they are not exactly like the Glass Mountains specimens. The costation is finer and the ears are provided with a denser brush of spines than usual on *R. paraindica*. Larger collections must be awaited to determine the true specific status of these specimens.

### Genus *Spinifrons* Stehli, 1954

*Spinifrons* Stehli, 1954:319.—Muir-Wood and Cooper, 1960: 287.—Williams et al., 1965:H497.

This genus was proposed for productaceans having the general appearance of *Dictyoclostus* but which have a tuft of large spines on the ears, large halteroid spines on the anteromedian part of the trail, and slender, hairlike spines on the brachial valve. This genus is extremely rare in the Glass Mountains.

TYPE-SPECIES.—*Spinifrons quadrata* Stehli (1954: pl.20: figs. 6-10).

DISCUSSION.—This is not a well known genus and

when preserved without its spines, is difficult to separate from *Reticulatia* Muir-Wood and Cooper and a number of other Dictyoclostidae. When well preserved, however, it is not difficult to recognize.

*Spinifrons delicatula*, new species

PLATE 385: FIGURES 1-12

Moderately large, transversely rectangular in outline, hinge widest part; ears large, approximating right angle. Sides nearly straight; anterior margin broadly rounded. Surface irregularly costate, umbonal region and part of venter of both valves finely reticulated; remainder of venter and trail marked by narrowly rounded costae of unequal size, about 4 in 5 mm. at front margin. Spines numerous, consisting of brush of large halteroid spines on ears and patch of large halteroid spines on anterior part of trail. Ornament spines slender and delicate, arising from fine rounded bases on costae. Brachial valve with venter finely reticulate, trail costate and entire surface provided with hairlike erect spines.

Pedicle valve strongly convex in lateral profile with maximum convexity near midvalve; anterior profile with broad, steep-sided dome. Umbo moderately swollen and extending moderately posterior to hinge when viewed from dorsal side. Median region inflated. Ears large and convex. Sulcus shallow and narrow, originating on venter and nowhere more than barely perceptible.

Brachial valve broadly concave with median region forming deepest part. Sides and anterior steep; ears concave and well demarcated.

MEASUREMENTS (in mm).—From locality USNM 711p, specimen 148929 (holotype): length 34.0, brachial valve length 26.2, surface length 59.0, hinge width 44.0, midwidth 39.9, height 20.3, thickness 6.8.

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (base)

LOCALITIES.—USNM 711p, 724p.

DIAGNOSIS.—Moderately large *Spinifrons* with delicate ornament and spines.

TYPES.—Holotype: USNM 148929. Figured paratypes: USNM 154015a, b.

COMPARISON.—Stehli's species, *S. quadrata*, at present the one described species, is the only one similar enough for comparison. It is a more robust shell, with stouter spines on the ears, a more coarsely

reticulate visceral disc region and stronger costae on the trail.

DISCUSSION.—The material on which this species is based consists of two fairly complete specimens, parts of four others, and two immature brachial valves. The details of the adult interior are not available. The young show a typical immature dictyoclostid cardinal process with bilobed myophore and large alveolus in the shaft. One of the fragments indicates that the lateral ridges were well developed in the adult. The posterior of a pedicle valve interior shows a wide, strongly dendritic, and slightly thickened adductor track.

*Spinifrons magna*, new species

PLATE 384: FIGURES 13-19; PLATE 385: FIGURES 13-26; PLATE 388: FIGURES 1-13; PLATE 389: FIGURES 1-14

Large, transversely rectangular, hinge widest part; ears well developed, moderately extended and narrowly rounded. Sides gently rounded; anterior margin broadly and gently rounded and usually indented slightly medially. Beak small and umbonal region low, just slightly elevated posterior to hinge. Surface with strongly but finely reticulated visceral disc; venter strongly convex and trail long and marked by fine costae about five or six per 10 mm on trail; costae low, rounded, with wide interspaces. Spines numerous; in brush on ears and scattered halteroid spines on trail; body spines small and scattered; diameter of halteroid spines 1 to 1.5 mm. Brachial valve with numerous long spines.

Pedicle valve narrowly convex in lateral profile, venter narrowly rounded, visceral disc forming posterior one-quarter, and trail anterior one-half. Anterior profile high, steep-sided dome. Visceral disc region gently inflated and with steep lateral slopes; sulcus originating on visceral disc, moderately deep and wide, extending to anterior margin. Flanks swollen.

Brachial valve with broad umbonal depression; visceral disc region flattened; geniculation narrowly rounded; trail about equal in length to visceral disc; ears broadly concave and demarcated by low, rounded ridge.

Pedicle valve interior with broadly flabellate diductor scars and elongated strongly dendritic but not thickened adductor field. Ginglymus narrow and concave. Ear baffles moderately thick in old specimens.

Brachial valve interior with strong lateral ridges and posterior platform; cardinal process widely trilobed, with elongated and thick median lobe. Brevisseptum strongly elevated anteriorly; brachial ridges large but with moderately elevated bounding ridge. Endospines small, stout, and densely arranged on geniculated slope.

MEASUREMENTS (in mm).—Brachial valve length of holotype 35.9; of others, unmeasurable.

	brach- ial valve length	sur- face length	hinge width	mid- width	height
USNM 728f					
148932a (holotype)	46.9	95.0	78.0	67.4	36.4
148932b	46.4	89.0	63.7	57.8	31.5
148932c	43.5	78.0	63.3	51.1	28.4

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation.

LOCALITIES.—AMNH 492, 497, 628, 629, 696; USNM 728f, 728h.

DIAGNOSIS.—Very large *Spinifrons* with relatively thin halteroid spines.

TYPES.—Holotype: USNM 148932a. Figured paratypes: USNM 148932b, c; 154011a-c, e-g; 154012a, 154013a-c, e, f; 154014-l; 154016a, d. Measured paratypes: USNM 148932b, c. Unfigured paratypes: USNM 154011d; 154013d; 154014a-k; 154016b, c.

COMPARISON.—This species is distinguished from the other two known species by its larger size, the relatively fine spines compared to the size, and the finer interior endospines.

DISCUSSION.—When fully grown this is a large and imposing species. In the adult form it is typically dictyoclostid in all details, but the young have features not usually seen. The smallest specimens have the usual attachment ring on the umbo and a scar of attachment surrounded by a circle of small spines. In the young the body spines of the pedicle valve are usually fairly long, attaining a length of 7.5 mm in a specimen 17 mm long. Dorsal spines appear on the brachial valve after about 5 to 7 mm of growth. The cardinal process of the young is variable, but very small specimens have a deep alveolous anterior to the myophore and the process itself is bilobed in ventral and posterior views. The two lobes of the young process are separated by a thin filling over the alveolus, which later becomes the

median lobe of the cardinal process. These characters appear in specimens measuring 10 mm in length. In specimens 15 mm long the alveolus is mostly filled in with shell matter, but the cardinal process is still strongly bilobed. It is bilobed at 20 mm of length and the valve geniculates at about 23 or 24 mm. At this length the cardinal process becomes distinctly bilobed and the median lobe is well established.

### *Spinifrons quadrata* Stehli

PLATE 384: FIGURES 1-12; PLATE 387: FIGURES 1-28; PLATE 390: FIGURES 1-7

*Spinifrons quadrata* Stehli, 1954:318, pl. 20: figs. 6-10.

This species is fairly common at USNM 728e (=AMNH 625). Generally the specimens have the valves separated and the occurrence suggests a death assemblage. Very small specimens have the attachment ring on the umbo so characteristic of the Productacea. The young brachial valve has an alveolus in the shaft which grows into the adult dictyoclostid as explained under *S. magna*.

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation

LOCALITIES.—AMNH 591, 625, 629, 631, 632; USNM 725c, 728e, 728h, 746.

TYPES.—Figured hypotypes: USNM 148931; 148942, 153842a, b; 153843; 154014a-g, i-k, m; 155035.

### Genus *Reticulatia* Muir-Wood and Cooper, 1960

*Reticulatia* Muir-Wood and Cooper, 1960:284.—Williams et al., 1965:H496.

This name was proposed for Dictyoclostidae having strongly and regularly reticulated visceral discs on both valves, no spines on the brachial valve, and those of the pedicle valve consisting of short body spines and halteroid spines clustered on the ears and distantly scattered on the trail slope.

TYPE-SPECIES.—*Productus huecoensis* R. E. King (1931.68, pl. 11: figs. 7a-c (not 8a, b)).

COMPARISON AND DISCUSSION.—Inasmuch as all dictyoclostids have a strong resemblance to one another, their separation is frequently attended by some difficulties; however, if close attention is paid to the arrangement of the halteroid spines, the trouble in identification is greatly lessened. *Reti-*



*culatia* can be detected by the strength and regularity of its reticulation on the visceral disc of both valves. Most species have at least half of the valve occupied by this regular reticulation. Some confusion of *Reticulatia* with *Spinifrons* Stehli, *Squamaria* Muir-Wood and Cooper, and *Peniculauris* Muir-Wood and Cooper may occur; but *Spinifrons* and *Squamaria* have the brachial valve strongly spinose and spine tufts on the ears.

*Reticulatia* appears to be best developed and commonest in the late Pennsylvanian and Wolfcampian in the Glass Mountains. It is commonest in the shales of the Wolfcampian, especially in parts of Kansas, Oklahoma, and north-central Texas.

### *Reticulatia americana* (Dunbar and Condra)

PLATE 383: FIGURES 14–22

*Dictyoclostus americanus* Dunbar and Condra, 1932:218, pl. 34: figs. 3–6.

*Reticulatia huecoensis* Muir-Wood and Cooper, 1960:284, pls. 104, 105.

Large; length and width nearly equal; hinge about equal to midwidth, ears fairly well developed although generally not extended laterally. Sides subparallel and anterior margin broadly rounded. Visceral disc of both valves reticulated with pattern of medium strength.

Pedicle valve strongly convex, with maximum convexity near midvalve, visceral disc region slightly flattened and trail gently rounded. Median region greatly swollen. Sulcus barely perceptible. Flanks rounded and with steep lateral slopes.

Brachial valve strongly geniculated and deeply concave with steep sides and front; umbonal region depressed; median fold barely perceptible. Ears flattened and separated by oblique ridges.

Brachial valve interior with large cardinal process, strong lateral and brachial ridges, and moderately developed posterior platform.

MEASUREMENTS (in mm).—From locality USNM 776 specimen 6651a, and from USNM 713h, specimen 148999a, respectively: length 50.6, 47.0; brachial valve length 43.6, 39.9; surface length 83.0, 80.0; hinge width 56.4, 54.0 (?); midwidth 57.0, 55.7; height 26.7, 24.2; thickness 12.4, unmeasurable.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (beds 5–8 of King), also Wolfcampian rocks outside the Glass Mountains.

LOCALITIES.—Neal Ranch: USNM 713h, 721n, 776.

DIAGNOSIS.—*Reticulatia* with length and width nearly equal and moderately strong reticulation of the visceral disc regions.

TYPES.—Figured hypotypes: USNM 148999a, b; 149002a. Measured hypotypes: USNM 6651a, 148999a.

COMPARISON.—Comparison is made with each of the species occurring in the Glass Mountains under their specific headings.

DISCUSSION.—The main characters of this species have been sketched here because a few Glass Mountains specimens appear to conform to this species, although they are uncommon. The species is abundant in Nebraska, where it was first described, and also in Kansas, appearing in both states in Wolfcampian rocks. In Oklahoma it is common in a robust variety in the Red Eagle Limestone. The Glass Mountains occurrence actually is slightly more coarsely reticulated than Kansas and Nebraska specimens but the proportions are those of *R. americana*.

Numerous fragments of a large *Reticulatia* with moderately strong reticulation suggesting this species were obtained in the residues from USNM 713h. In addition to the fragmentary specimens a poor but large pedicle valve is also present. This is a strongly convex shell with a fairly even lateral profile. The median sulcus is not apparent on the visceral disc but a faint suggestion of a sulcus appears on the anterior trail slope. The reticulation of the visceral disc is moderately coarse. Affinities with *Reticulatia americana* (Dunbar and Condra) appear in the quadrate form, the moderately strong reticulate visceral disc, and the lack of a definite sulcus.

None of the brachial valves from the acid residues is complete and they have suffered somewhat from the etching. The visceral disc reticulation seems finer than that of the large pedicle valve mentioned above, but the brachial valves are of smaller specimens. An etched specimen preserving an ear retains the bases of a tuft of very stout spines, somewhat stouter than those figured by Dunbar and Condra (1932, pl. 34: fig. 4a).

The etch material is of considerable interest because it includes a number of small and immature specimens before geniculation had taken place. The pedicle valves are evenly and gently convex

while the brachial valves are nearly flat. The cardinal process of these young specimens is somewhat elongate and the shaft is anteriorly excavated.

***Reticulatia huecoensis* (R. E. King)**

PLATE 378: FIGURES 14–17

*Productus huecoensis* R. E. King, 1931:68, pl. 11: figs. 7a–c [not fig. 8].

Large, transversely rectangular in outline; hinge wider than midwidth; ears moderately extended, obtusely rounded. Sides slightly rounded; anterior margin broadly rounded to nearly straight. Surface finely costate in anterior half, finely reticulate in posterior half; concentric wrinkles fine and even except on posterior margin inside ears, where they are strongest; costae fine and closely crowded, numbering four or five per 5 mm at front margin except where thickened anterior to spine bases. Spines scattered; halteroid spines forming tufts of slender spines on ears, and scattered spines on entire trail surface arising from small rounded bases; visceral disc probably with small body spines.

Pedicle valve lateral profile strongly and evenly convex but with umbonal region strongly incurved; anterior profile high, steep-sided dome. Umbonal region narrowly swollen, protruding only short distance posterior to hinge; median region strongly inflated. Sulcus originating on anterior part of visceral disc, shallow and barely perceptible. Flanks gently rounded.

Brachial valve with visceral disc region evenly and gently convex; geniculation occurring at about two-thirds valve length from beak, abrupt and nearly at right angles to form steep sides and anterior and deeply concave valve. Visceral disc finely reticulate.

MEASUREMENTS (in mm).—From King locality 380, specimen YPM 10554 (holotype): length 44.2, brachial valve length 33.9, surface length 96.0, hinge width 60.2\* (based on half measure), midwidth 53.2, height 28.4, thickness 14.9.

STRATIGRAPHIC OCCURRENCE.—Gaptank, Hueco, Neal Ranch formations.

LOCALITIES.—Gaptank: USNM 704d. Hueco: King 380. Neal Ranch: USNM 701b, 715b, 719a.

DIAGNOSIS.—Large *Reticulatia* with finely marked visceral disc regions.

TYPE.—Holotype: YPM 10554.

COMPARISONS.—This species has been confused with *R. americana* Dunbar and Condra, and the latter was placed in synonymy of *R. huecoensis* (R. E. King) by Muir-Wood and Cooper (1960: 284). This appears to be a mistake, because comparison of the two species shows clearly that the reticulated visceral disc region of *R. huecoensis* has a finer texture than that of the Nebraska and Kansas species. Other differences also exist: the Texas species is more rectangular because it is shorter than *R. americana*, which is squarish in outline; *R. huecoensis* is more strongly and more abruptly geniculated than *R. americana*; and the umbonal region of *R. huecoensis* protrudes farther posterior to the hinge than does that of *R. americana*. The fineness of the reticulation of the visceral disc regions distinguishes *R. huecoensis* from all other species of *Reticulatia* in the Glass Mountains.

***Reticulatia robusta*, new species**

PLATE 386: FIGURE 1; PLATE 392: FIGURES 1–6

*Productus semireticulatus hermosanus* R. E. King (part, not Girty), 1931:73, pl. 14: fig. 16.

Large, transversely rectangular in outline; hinge forming widest part; ears moderately large; sides rounded; anterior margin broadly and gently rounded; surface semireticulate, reticulate pattern moderately fine on visceral disc; trail costae narrowly rounded, with interspaces nearly as wide as costae numbering about five per 10 mm at front margin. Posterior margin with row of spines; ears with tuft of stout halteroid spines; trail with few stout, scattered halteroid spines.

Pedicle valve in lateral profile strongly convex, maximum convexity near midvalve; anterior profile broadly domed, with steep sides and slightly narrowed top. Umbonal region gently convex, widening rapidly into visceral disc and protruding slightly posterior to hinge. Median region greatly inflated. Sulcus originating on anterior side of umbonal region and extending to front margin, shallow, and ill-defined. Flanks bounding sulcus convex and steep-sided.

Brachial valve with visceral disc wholly and moderately finely reticulated, gently concave with broad shallow pit at umbo; geniculation taking place about two-thirds distance from posterior margin,

approximating right angle and forming deepest part of valve; ears moderate in size, well demarcated. Sides and anterior steep.

Pedicle valve interior not known. Brachial valve interior with moderately developed lateral ridge and large trilobed cardinal process.

MEASUREMENTS (in mm).—From locality USNM 701d, specimen 148997 (holotype): length 52.0, brachial valve length 43.9, surface length 106.0?, hinge width 73.6\* (based on half measure but slightly incomplete), midwidth 67.2, height 34.7, thickness 20.0.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (Beds 2, 4, 12–14 of P. B. King), Lenox Hills Formation, Cibolo Formation.

LOCALITIES.—Neal Ranch: USNM 701, 701c, 701d, 701–1, 706x, 712w, 712z, 721g. Lenox Hills: USNM 742d. Cibolo: USNM 738n.

DIAGNOSIS.—Widely transverse, large *Reticulatia* with moderately strong reticulation.

TYPES.—Holotype: USNM 148997. Figured paratypes: USNM 148996, 153840.

COMPARISONS.—This species is readily distinguished from *R. huecoensis* (King) by its larger size and the greater strength of the reticulation of the visceral disc. It is also readily distinguished from *R. americana* (Dunbar and Condra) by its greater width and widely rectangular outline. It has a more strongly costate trail than that species. *Reticulatia robusta* differs from *R. species 1*, from the Neal Ranch Formation (bed 9–12) in having a less strongly costate trail, much more transverse outline, and a less prominent sulcus.

### *Reticulatia species 1*

PLATE 393: FIGURES 1–10

Large, transversely rectangular in outline, greatest width at hinge; ears large, extended. Sides rounded; anterior margin broadly rounded. Surface semireticulate, visceral disc fairly strongly reticulate, trail slightly more than half length, being costate with costae distant and narrowly rounded, numbering 5 per 10 mm at front margin. Spines scattered: tuft of fine halteroid spines on ears and scattered spines on trail; spines on visceral disc few and scattered.

Pedicle valve strongly and fairly evenly convex in lateral profile; anterior profile high, broad dome.

Umbonal region narrowly swollen, with long steep umbonal slopes; median region swollen. Sulcus originating on umbonal region, narrow and deep, extending to anterior margin; flanks bounding sulcus, well rounded and moderately swollen.

Brachial valve with gently concave visceral disc; geniculated slightly posterior of midvalve nearly at right angle; fold prominent, originating at umbonal region and extending to front margin, broadly subcarinate. Ears flattened and extended. Cardinal process small.

Figured specimens: USNM 149018; 148994a, b.

MEASUREMENTS (in mm).—From locality USNM 701c, specimens 148994a and b, respectively: length 50.5, 47.0; brachial valve length 40.1, (?); surface length 102.0, 98.0; hinge width 67.4+, 71.6\*; midwidth 65.7, 60.3; height 33.0, 29.3; thickness 14.6, (?).

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation.

LOCALITIES.—USNM 701a<sup>1</sup>, 701c, 731.

DIAGNOSIS.—Large *Reticulatia* with a deep, narrow sulcus, and moderately coarse reticulation.

COMPARISONS.—This species is readily distinguished from *R. americana* (Dunbar and Condra) by its deep sulcus. It is distinguished from *E. species 2*, which is also sulcate, by its much larger size, stronger sulcus, and more transversely rectangular outline. It is distinguished from *R. huecoensis* (R. E. King) by its coarser visceral disc and from *R. robusta*, new species, by the stronger median sulcus and stronger costae on the trail.

### *Reticulatia species 2*

PLATE 378: FIGURES 18–20; PLATE 392: FIGURES 7–10

Large, subquadrate outline, hinge slightly wider than midwidth; sides gently rounded; anterior margin broadly rounded. Surface semireticulate, reticulate visceral disc occupying about half shell length; reticulation moderately coarse; trail slope costate, costae variable, broad and low, 3 per 10 mm on trail. Spines not preserved.

Pedicle valve strongly and fairly evenly curved, but most convex in umbonal region; anterior profile high, steep-sided dome with median depression. Umbonal region moderately and widely swollen, protruding about  $\frac{1}{5}$  valve length posterior to hinge. Median region strongly swollen; sulcus originating

in umbonal region, shallow and moderately wide, extending to anterior margin; flanks bounding sulcus broadly swollen and moderately convex.

Brachial valve not known.

Figured specimens: USNM 148998, 149005.

MEASUREMENTS (in mm).—From locality USNM 701v, specimen 148998: length 45.6, surface length 85.0, hinge width 48.8, midwidth 52.0, height 27.3.

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member).

LOCALITY.—USNM 701v.

COMPARISONS.—This species is a compact form of moderate size having a squarish outline and thus suggesting *R. americana* (Dunbar and Condra). It differs from that species, however, in having a strong sulcus extending from the umbonal region to the anterior margin. Its visceral disc is also somewhat more strongly marked than that of *R. americana*.

### Genus *Antiquatonia* Miloradovitch, 1945

*Antiquatonia* Miloradovitch, 1945:496 (as emended by Sarycheva, 1949:167).—Sarycheva and Sokolskaja, 1952:145; Muir-Wood and Cooper, 1960:270.—Williams et al., 1965: H495.

Dictyoclostidae with strongly reticulate visceral discs, usually medium size to large, subquadrate to subrectangular in outline, and with large extended ears. Pedicle valve with deep sulcus and long trail. Lateral slopes marked by a curved ridge bearing long, stout halteroid spines overhanging the ears (the chief feature, giving this group of species generic status).

TYPE-SPECIES.—*Productus antiquatus* J. Sowerby (1821:15, pl. 317: figs. 1, 5, 6).

DISCUSSION.—*Antiquatonia* has proved to be a rare fossil in the Glass Mountains and Sierra Diablo. So far it has been found chiefly in the upper Gaptank Formation and in the Wolfcampian Formations. Material taken from the Glass Mountains is generally poorly preserved and the interior details are seldom good. But the specimens from the Bone Spring Formation are excellent and furnish good illustration. The genus is very largely based on the spine-bearing curved ridge that appears on the slopes over the ears. The ridge produces modifications of the ear on the interior that seem to serve the same purpose as the ear baffle produced by such other genera as *Paucispinifera* Muir-Wood and Cooper and *Liosotella* Cooper.

### *Antiquatonia costella*, new species

PLATE 453: FIGURES 30–33

Large, transversely rectangular, greatest width at hinge; sides slightly rounded; anterior margin broadly rounded; visceral disc forming about posterior half, finely reticulated; trail forming anterior half, marked by fairly even costellae, about 5 per 5 mm at anterior. Spines, as revealed by bases, in row of four large ones on lateral curved ridge and one large one on each ear; few large spines scattered on trail. Curved ridge over ear not strongly developed.

Pedicle valve very strongly convex in lateral profile, convexity fairly even and greatest near mid-valve; anterior profile, broad dome slightly rounded at top but with slight medial depression and very steep sides flaring at base. Umbonal region fairly strongly swollen but not protruding far posterior to hinge. Sulcus fairly broad and shallow, originating just anterior to umbo.

Brachial valve poorly preserved but having finely reticulated visceral region, depressed umbo, and broad, gently elevated fold.

MEASUREMENTS (in mm).—From locality USNM 715b, specimen 153931 (holotype): length 38.7, brachial valve length 27.0?, surface length 75.0, midwidth 67.7, hinge width 69.6, height 26.4, thickness unmeasurable.

STRATIGRAPHIC OCCURRENCE.—Lenox Hills Formation (Neal Ranch Formation of Ross 1963).

LOCALITY.—USNM 715b.

DIAGNOSIS.—Large, finely reticulated *Antiquatonia* with finely costellate trail.

TYPES.—Holotype: USNM 153931.

COMPARISON.—This species resembles *A. hessensis* (R. E. King) but is a much larger, wider, more robust and convex shell than that species. It is also similar to *A. regularis*, new species, but is larger, wider, and has a more finely costellate trail. Furthermore, the curved ridge over the ears is less prominent than that of *A. regularis*.

### *Antiquatonia hessensis* (R. E. King)

PLATE 391: FIGURES 6–17

*Productus hessensis* R. E. King, 1931:68, pl. 11: fig. 6 (only)

Subquadrate outline, width slightly greater than length; sides rounded; anterior margin broadly rounded and slightly emarginated medially. Hinge wider than midwidth; ears large and extended. Sur-



face with posterior half finely reticulated and anterior half finely costate. Spine arrangement not clearly known except for row of heavy spines on ridges, overhanging ears.

Pedicle valve narrowly convex in lateral profile, posterior third slightly flattened but anterior third moderately convex, median third narrowly rounded. Umbonal region flattened and with short umbonal slopes. Median region strongly swollen. Sulcus originating on umbonal region, moderately deep and wide and extending to anterior margin. Flanks bounding sulcus moderately swollen and rounded. Base of lateral slope marked by strong, narrowly rounded, curved, spine-bearing ridge.

Brachial valve strongly geniculated at midvalve; visceral disc gently concave but trail strongly bent dorsally to form deep concavity; ears set off by curved grooves corresponding to ridges on pedicle valve.

Brachial valve interior with short stout cardinal process; moderately strong lateral ridges and moderately thickened adductor field.

MEASUREMENTS (in mm).—Thickness of holotype unmeasurable.

	brach- ial valve length	sur- face length	hinge width	mid- width	height
King 106					
YPM 10651 (holotype)	34.0	?	67.0?	?	46.8
USNM 705b					
148975a	?	29.5	45.0	?	54.3
148975b	?	25.0	34.0	51.0	40.4

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (base).

LOCALITIES.—King 106; USNM 705a, 705b, 708q, 714e, 715v, 719q, 719y, 720e.

DIAGNOSIS.—Fairly large *Antiquatonia* with finely reticulate visceral disc and finely costate trail.

TYPES.—Holotype: YPM 10651 (casts USNM 148982). Figured hypotypes: USNM 148975a, b; 148979.

COMPARISONS.—This species is most similar to *Antiquatonia planumbona* Stehli from the lower Bone Spring Formation in the Sierra Diablo. The visceral disc of the brachial valve of both species is very finely and evenly reticulate but the pedicle valves are not similar. That of *A. planumbona* is much more deeply sulcate and the reticulation of

the visceral disc is coarser than that of the brachial valve and also coarser than that of *A. hessensis*. Other differences between the two species are: in *A. planumbona* the umbonal region, although flattened, is more inflated than that of *A. hessensis*, and the trail is more coarsely costate and is not as long.

DISCUSSION.—The type lot of *Productus hessensis* consists of four groups of specimens, three of which are not conspecific with the holotype. The holotype (by original designation) is the specimen refigured herein, which belongs to the genus *Antiquatonia*. Lot YPM 10654, which comes from the west side of the Wylie Mountains, is *Dasysaria undulata* Cooper and Grant (1969) and comes from Wolfcampian rocks. Lot T10716, belonging to the Bureau of Economic Geology, Austin, Texas, is likewise from the Wylie Mountains and belongs to *Dasysaria undulata*. Lot YPM 10655 consists of a single specimen that belongs to *Thamnusia silicica*, new species.

*Antiquatonia hessensis* is a rarity in the Glass Mountains and no good specimens have been found in silicified form.

### *Antiquatonia inflativentra*, new species

PLATE 386: FIGURES 2-9

Medium size for genus, transversely rectangular in outline, width greater than length; hinge wider than midwidth; ears extended and prominent. Sides gently rounded; anterior margin very broadly rounded to flattened. Surface finely reticulated over umbonal region and venter; trail finely costate, costae numbering four per 5 mm at front margin; concentric undulations closely spaced, strongest on lateral slopes; halteroid spines sparsely scattered; row on posterior margin and one spine on ear extremity; curved row of large stout spines on curved ridge near base of lateral slope; scattered halteroid spines on anterior trail slope and small body spines on visceral disc. Brachial valve without spines.

Pedicle valve strongly and evenly convex in lateral profile, bringing surface of umbonal region roughly parallel to surface of anterior trail slope; anterior profile a high dome with precipitous sides and gently convex crown. Umbonal region flatly convex and with short gentle umbonal slopes; venter strongly inflated; trail gently convex in both profiles; sulcus originating on umbonal region, narrow and shallow, widening and deepening anteriorly but not strong on any part of valve. Flanks bound-



ing sulcus gently rounded. Ears forming acute angle but with narrowly rounded extremity. Lateral slopes with low, curved, spine ridge thickening and elevating toward margin.

Brachial valve strongly geniculated, reticulated visceral region occupying slightly less than half surface length; visceral disc region gently concave; valve deepest at place of geniculation, sides and anterior steep; ears well demarcated. Fold originating on visceral disc, low and inconspicuous.

Pedicle valve interior unknown. Brachial valve interior with stout cardinal process bilobed on ventral face but with trilobed myophore.

MEASUREMENTS (in mm).—thickness of USNM 148965a, 12.2; of others, unmeasurable.

	length	surface length	hinge width	mid- width	height	thick- ness
USNM 701e						
148965a	32.2	?	57.0	46.6*	41.3	18.4
148965b	30.0	?	65.0	48.0*	40.6	21.9
148965c	30.0	?	62.0	46.6*	40.6	21.0
(holotype)						
148965d	?	25.4	49.0	46.4*	38.3	?
148965e	31.4	23.3	58.0	47.4*	37.0	19.3

STRATIGRAPHIC OCCURRENCE.—*Uddenites*-bearing shale Member of Gaptank Formation; Neal Ranch Formation.

LOCALITIES.—Gaptank: USNM 700f. *Uddenites*: USNM 701e, 701q, 701r, 701v, 703–l. Neal Ranch: USNM 701.

DIAGNOSIS.—Strongly convex *Antiquatonia* with finely reticulated visceral disc.

TYPES.—Holotype: USNM 148965c. Figured paratypes: USNM 148965b. Measured paratypes: USNM 148965a, b, d, e. Unfigured paratypes: USNM 148965a, d, e.

COMPARISONS.—This species differs from *A. hesensis* (R. E. King) in its narrower form, less well developed sulcus on the pedicle valve, stronger and less regular reticulation of the visceral discs of both valves, and a somewhat more swollen umbonal region.

*Antiquatonia inflativentra* is distinguished from *A. regularis*, new species, by its narrower form, more sulcate pedicle valve, and less regular strong reticulation of the visceral disc.

This is an uncommon species in the Glass Mountains and has not been found silicified.

## *Antiquatonia planumbona* Stehli

PLATE 390: FIGURES 8–22

*Antiquatonia planumbona* Stehli, 1954:316, pl. 20: figs. 1–5.

Medium size for genus, wider than long, ears prominent and widely extended. Sides rounded; anterior margin broadly rounded and deeply indented medially by sulcus. Sulcus strongly but finely reticulated, reticulation dying out on venter; trail marked by low, rounded, crowded costae, about seven or eight per 10 mm. Spines scattered; row of halteroid spines on posterior margin; row on curved elevation overhanging ears and few scattered ones on anterolateral and anterior slopes. Brachial valve without spines but with reticulation of visceral disc somewhat finer than that of pedicle valve.

Pedicle valve strongly convex in lateral profile, but broadly domed and deeply indented medially in anterior profile. Visceral disc gently swollen; umbo slightly extended posterior to posterior margin; venter strongly rounded; trail convex. Sulcus originating near middle of visceral disc, narrow, moderately deep and extending to anterior margin.

Brachial valve with broad and shallow umbonal depression; visceral disc gently concave, deepest at place of geniculation about two-thirds length from beak; fold originating on anterior side of umbonal depression, strong, subcarinate, and most strongly marked at place of geniculation. Ears demarcated by sharp oblique fold.

Pedicle valve interior with adductor track on fold produced by sulcus but not strongly thickened. External curved fold on lateral slopes producing strong fold internally acting as ear baffle. Ginglymus well developed.

Brachial valve interior with low and wide, trilobed cardinal process; adductor field wide, strongly impressed, and strongly but finely dendritic; brevisseptum low; brachial ridges well developed and with thickened rims. Lateral ridges not extended from thick posterior platform.

MEASUREMENTS. (in mm).—From locality USNM 728f, specimens 148988a and 148987, length 31.4, 35.7; brachial valve length 26.0, (?); surface length 55.0, 71.0; hinge width 48.2, 52.2; midwidth 47.8, 41.4; height 21.4, 24.5; thickness 9.5, (?).

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation.

LOCALITIES.—AMNH 625, 629, 631, 697; USNM 728e, 728f.

**DIAGNOSIS.**—Finely reticulate *Antiquatonia* with deep sulcus and subdued, curved ridge on lateral slopes.

**TYPES.**—Lectotype: AMNH 27299/2:1. Figured paratype: AMNH 27299/2:2.5. Figured hypotypes: USNM 148987; 148988a, b; 153844. Measured hypotypes: USNM 148987, 148988a.

**COMPARISON.**—This species is most like *A. hesensis* (R. E. King) and is compared under that species. It is also more deeply sulcate than any of the other species described herein.

**DISCUSSION.**—This is a very rare species in the Sierra Diablo. Stehli had only a few specimens and we have only about 20 in all states of preservation and fragmentation. It is interesting to note that the curved ridge on the slope of the pedicle valve results in a strong ridge inside the brachial valve which has a deep groove on its outer side. This ridge undoubtedly serves as an ear baffle.

### *Antiquatonia regularis*, new species

PLATE 391: FIGURES 1-5

Fairly large for genus, wider than long, outline transversely rectangular. Hinge wide, at least equal to midwidth. Sides moderately rounded; anterior margin broadly rounded to flattened. Visceral disc strongly but finely reticulated. Ears separated from lateral slopes by low, curved, spine-bearing ridge; trail costate, costae numbering four or five per 5 mm at anterior margin. Halteroid spines; row of three or more on posterior margin and ears; curved row on ridge at base of lateral slopes; few scattered slender spines on trail slope.

Pedicle valve strongly convex in lateral profile, greatest convexity near midvalve, anterior part moderately convex but posterior somewhat flattened; anterior profile a high steep-sided dome with gently convex top. Umbonal region fairly strongly swollen, and with moderately steep slopes; median region including posterior part of trail and anterior part of visceral disc strongly swollen; trail costate, occupying about anterior half.

Visceral disc gently concave but valve strongly geniculated to produce shell with greatest concavity near line of geniculation. Umbonal region faintly concave; fold originating just anterior to umbonal depression, low and broad at anterior.

Interior unknown.

**MEASUREMENTS** (in mm).—From locality USNM

715, specimen 148972a (holotype): length 36.3, surface length 70.0, hinge width 47.0 (slightly incomplete), midwidth 47.7, height 22.4.

**STRATIGRAPHIC OCCURRENCE.**—Lenox Hills Formation.

**LOCALITIES.**—USNM 707j, 707m, 707o, 715.

**DIAGNOSIS.**—Robust *Antiquatonia* having a strongly reticulate visceral disc occupying half the shell length.

**TYPES.**—Holotype: USNM 148972a. Unfigured paratypes: USNM 148972b, 148973.

**COMPARISONS.**—In the regularity and strength of the reticulation of the visceral disc, this species suggests *A. hesensis* (R. E. King), but that species has a much finer net of reticulation and also much finer costae on the long trail. *Antiquatonia regularis* is larger and more strongly and regularly reticulate than *A. inflativentra*, new species.

**DISCUSSION.**—This species is extremely rare in the Glass Mountains and has only been found in an unsilicified condition in coarsely clastic limestone conglomerate, where it occurs with numerous goniatites (e.g., USNM 707j, 715).

### *Antiquatonia* species indeterminate

A few specimens that have proved indeterminable are listed as *Antiquatonia* species in the lists. Two, representing a small species, are from USNM 708q and 709t; another is from USNM 700g.

### Genus *Peniculauris* Muir-Wood and Cooper, 1960

*Peniculauris* Muir-Wood and Cooper, 1960:278.—Williams et al., 1965:H495.

This name was proposed for large, semireticulate dictyoclostid productids having an irregularly semireticulate visceral disc region, numerous small body spines on the visceral disc and trail, but a brush of fairly slender but long halteroid spines on the ears. The brachial valve has numerous small spines. Internally the structures are typically dictyoclostid but not greatly exaggerated in old adults. Generally the adductor platform of the pedicle valve is not greatly thickened but the cardinal process is commonly large, spreading, and strongly trilobed.

**TYPE-SPECIES.**—*Peniculauris mckeei* Muir-Wood and Cooper, (1960:280, pl. 100: figs. 1-7, pl. 101: figs. 1-3, junior synonym of *Aulosteges subcostatus* King, 1931:94, pl. 25: figs. 5-7).

COMPARISONS.—This genus may be confused with *Squamaria* Muir-Wood and Cooper, which is marked like it, but that genus has a brush of spines on the ears of the brachial valve as well as on those of the pedicle valve. *Peniculauris* may also be confused with *Dasysaria* Cooper and Grant, but that genus lacks spines on the brachial valve, the ornament is much finer, and the visceral disc more finely reticulated.

DISCUSSION.—*Peniculauris* appears first in the Skinner Ranch Formation (Decie Ranch Member) but is not abundant at this level, perhaps not being entirely happy in the rigorous environment of that zone. It is next encountered in the Hess Formation (Taylor Ranch Member = "fossil bed" of P. B. King). It is abundant in shaly rock of this member along the crest of the mountains for a mile or two (USNM 702d, e, f, m).

Higher, in the Leonardian, it appears sporadically but is found in great abundance in the shaly Cathedral Mountain Formation in the Split Tank region and for some distance to the east (USNM 703b, 702, 702un, and 726y). It occurs frequently in the shale at the top of the Cathedral Mountain Formation at, and in the immediate vicinity of, Clay Slide. The genus survives into the Road Canyon Formation but it is not common. It has not been seen higher, in the limestone members of the Word Formation or in the shaly beds between them.

### *Peniculauris costata*, new species

PLATE 399: FIGURES 1–10; PLATE 400: FIGURES 1–10; PLATE 401: FIGURES 1–8

*Productus indicus* R. E. King (not Waagen), 1931:72, pl. 13: figs. 6a–c.

Very large, transversely rectangular to nearly square in outline, hinge forming widest part, ears large, rounded, and protruding. Sides gently convex; anterior margin broadly rounded. Surface costate and spinose; costae strong and elevated, separated by spaces equal in width to costae, 3 or 4 costae per 10 mm on trail; visceral disc region of pedicle valve reticulated by irregular concentric wrinkles; reticulation not as strongly marked or as regular as on brachial valve; trail with strong distant costae. Spines numerous; row along hinge, often recurved posteriorly and forming row on costae.

Pedicle valve strongly and fairly evenly convex in lateral profile but umbonal region somewhat more strongly curved; anterior profile, high, steep-sided dome bearing narrow median depression. Umbonal region wide but only gently swollen and protruding slightly posterior to posterior margin. Umbonal slopes short, moderately steep. Median region greatly inflated. Sulcus originating on umbonal region, narrow, fairly deep, and extending

#### MEASUREMENTS (in mm).—*Peniculauris costata*, new species:

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 707e							
148832a	64.1	47.2	125+	90.0*	81.0*	48.0?	33.3
148832b	53.3	37.7	102.0	78.8*	62.0*	30.6	?
148832e	48.0	?	82.0	72.8	50.8	28.7	?
148832f	30.3	25.0	48.0	48.0	42.8	16.3	5.0
USNM 703d							
148831c	52.0	37.2	102.0	71.6	60.0	35.1	18.2
(holotype)							
148829	61.1	?	116.0	83.5	67.7	39.0	?
USNM 703c							
148830	45.3	32.0	94.0	68.7	50.0	32.8	18.2

to anterior margin. Flanks bounding sulcus moderately rounded. Ears large and swollen.

Brachial valve with strongly reticulate visceral disc and strong geniculation. Visceral disc gently concave; valve deepest at place of geniculation and

with steep sides and anterior. Ears concave and well demarcated. Median fold originating just anterior to shallow umbonal depression, broadly carinate and extending to the anterior margin, usually low but well-marked.

Pedicle valve interior with broad but not greatly thickened adductor platform; diductor scars large and flabellate; ridges bounding outside of diductors poorly developed.

Brachial valve interior with large, sessile, trilobate cardinal process; lateral ridges strong; ear swollen or with low ridge; adductor field not thickened; brachial ridges moderately developed. Visceral area bounded by low ridge; endospines short and stout.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—AMNH 503; USNM 703, 703c, 703d, 707e, 710i, 710u, 719x, 720d, 721j, 721x, 722e, 724b, 724c, 724j, 726d.

DIAGNOSIS.—Large, distantly costate *Peniculauris*.

TYPES.—Holotype: USNM 148831c. Figured paratypes: USNM 148829; 148830; 148831a b, d; 148832; 148833. Measured paratypes: USNM 148829; 148830; 148832a, b, e, f. Unfigured paratypes: USNM 148831b.

COMPARISONS.—This species is similar to *P. subcostata* (R. E. King) but differs in having stronger and more distant costae on the trail, stronger reticulated visceral disc, usually wider hinge and somewhat more transverse body. This species attains a larger size than *P. subcostata*. *Peniculauris costata* is more strongly ribbed than *P. bassi* (McKee) from the Grand Canyon and appears to be a larger shell when fully grown.

### *Peniculauris imitata*, new species

PLATE 401: FIGURES 9–13; PLATE 402: FIGURES 1–12

*Productus ivesi* R. E. King (part, not Newberry) 1931:69.

Medium size for genus, subquadrate outline, hinge forming widest part. Hinge wide, extended into convex, rounded ears protruding slightly beyond midwidth. Sides subparallel; anterior margin broadly rounded and indented slightly medially. Surface with visceral disc reticulated about to venter; trail and venter costate, costae variable, numbering about five per 10 mm in middle of trail, but becoming more numerous anteriorly. Spines usually small and delicate; ears with thick brush of thin and delicate spines; trail with numerous short, thin spines and occasional scattered thin halteroid spines. Brachial valve with numerous

small, delicate ornament spines.

Pedicle valve strongly convex in lateral profile, visceral disc surface and trail surface nearly parallel; anterior profile high, steep-sided dome; geniculation narrowly rounded. Umbonal region swollen and with steep posterolateral slopes. Median region inflated. Sulcus variable, originating on visceral disc and deepening anteriorly to anterior part of trail, there becoming shallow or disappearing. Sulcus obsolete on a few specimens. Flanks rounded and with nearly vertical sides.

Brachial valve with visceral disc occupying about half length, strongly geniculated at about right angle; greatest depth just posterior to geniculation; visceral disc reticulated; sulcus poorly defined and barely perceptible in some specimens. Ears flattened but slightly concave and demarcated by low ridge.

Pedicle valve interior with slightly defined ginglymus; adductor field moderately thickened, wide posteriorly, and with posterior scars dendritic.

Brachial valve interior with narrow posterior platform and low cardinal process strongly bilobed and commonly widely spreading in old shells. Cardinal process anteriorly buttressed by low rounded ridge uniting near midvalve with brevisseptum, which is elevated and bladelike anteriorly. Brachial ridges large and with thick rims. Adductor field large, commonly thickened and strongly dendritic.

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation, Hess Formation (Taylor Ranch Member).

LOCALITIES.—Bone Spring: AMNH 492. Hess: USNM 715q, 726n. Taylor Ranch: 702d, 702e, 702f, 702m, 713x, 716n, 716o, 722p.

DIAGNOSIS.—Medium-sized *Peniculauris* with small ears and fairly strong but variable sulcus.

TYPES.—Holotype: USNM 148823b. Figured paratypes: USNM 148792a, b; 148798a, b; 148826a; 153995b. Measured and unfigured paratypes: USNM 148823a; 148798a; 148792a, b; 148801a; 148818. Unfigured paratypes: USNM 153995a.

COMPARISON.—Like nearly all productids, this one is variable and we do not have a really large collection of them. Commonly, when found loose on the outcrop, most of the specimens have lost at least one ear because the tuft of spines on the ear causes the matrix to cling tenaciously at this point but releases other parts of the shell more readily.

MEASUREMENTS (in mm).—*Peniculauris imitata*, new species:

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702d							
148792a	58.9	40.0?	112.0	64.6*	52.7	32.7?	?
148792b	50.5	38.4	108.0	65.4	61.0	35.9	24.2
USNM 716o							
148823a	59.7	?	115.0	74.4*	56.0	38.6	?
148823b	52.8	?	98.0	56.0	50.8	26.8	?
(holotype)							
USNM 702f							
148798a	50.4	?	91.0?	57.4	46.2	26.0?	?
USNM 715q							
148818	54.5?	40.6	90.0?	63.0*	59.0	32.0?	14.0
USNM 716n							
148801a	39.0	31.3	90.0	47.6	44.4	31.2	14.8

Although, comparisons may be made with other species, examination of a good collection is needed. This species is most like *P. subcostata* (R. E. King); some individual specimens in their variation are almost indistinguishable and the measurements are similar. *Peniculauris imitata*, however, is generally smaller, the ears are not so strongly developed, the pedicle valve is not so swollen, and the body cavity is less deep. The costae of the trail are usually finer than those of the Cathedral Mountain species, especially at the anterior. The sulcus of both species is variable. The brachial valve of the Taylor Ranch species is usually narrower and the trail longer than in *P. subcostata* (R. E. King). This species is considerably smaller than *Peniculauris* species 1, from the Skinner Ranch Formation, and has a narrower sulcus and smaller ears.

*Peniculauris ivesi* (Newberry)

PLATE 397: FIGURES 9–13

*Productus ivesi* Newberry 1861:122, pl. 2: figs. 1–8.—McKee, 1938:238, pl. 45: fig. 5.

Medium size for genus, subquadrate outline, greatest width at hinge; lateral margins flattened, sloping medially; anterior margin rounded. Ears prominent, convex. Surface with visceral disc obscurely reticulated but shown best on brachial valve; ears with brush of fairly thick spines; spine bases on venter suggesting presence of small spines.

Pedicle valve strongly convex in lateral profile,

maximum convexity posterior to midvalve; anterior profile high dome with indented top and steeply sloping sides. Sulcus originating on umbo and extending to anterior margin, moderately deep but narrow.

Brachial valve moderately concave, strongly reticulated on visceral disc region; most concave just posterior to place of geniculation. Umbo circular depression; fold low and narrow.

Brachial valve interior with fairly long cardinal process, myophore facing dorsad; posterior platform small; brachial ridges extending directly laterally, lightly impressed.

MEASUREMENTS (in mm).—Specimens USNM 5356a (lectotype) and b, respectively: length 43.0, (?); brachial valve length 33.0, 28.2; surface length 78.0, (?); midwidth 42.8, 43.0; hinge width 50.8, 51.0?; height 21.0?, (?); thickness 18.0, (?).

STRATIGRAPHIC OCCURRENCE.—Kaibab Formation.

LOCALITY.—Banks of Colorado River near mouth of Diamond River, Grand Canyon, Arizona, according to the label. The catalogue entry reads, "Mesa west of Little Colorado (Camp 70)," which is probably the correct locality.

DIAGNOSIS.—Medium-sized *Peniculauris* with narrow fold and wide hinge.

TYPES.—Lectotype: USNM 5356a. Figured paratypes: USNM 5356b. Unfigured paratype: USNM 5356c.

COMPARISON.—This species is smaller than any of the Glass Mountains species except *P. peniculifera*, new species, to which it has no other similarity. In appearance *P. ivesi* is like *P. subcostata*



(= *P. mckeei* Muir-Wood and Cooper), but is much smaller. It is also much smaller than *P. bassi* (McKee).

***Peniculauris peniculifera*, new species**

PLATE 406: FIGURES 1-9; PLATE 407: FIGURES 1-5

Small for genus, subquadrate in outline, hinge forming widest part; ears extended and narrowly rounded; sides nearly straight; anterior margin broadly rounded. Surface crudely semireticulate, posterior half of each valve marked by concentric undulations and costae; reticulation of brachial valve more regular than that of opposite valve; trail finely costate, with about 3 costae per 5 mm near front. Surface spinose; dense brush of strong halteroid spines on ears attaining length of 75 mm; fine delicate spines on small rounded bases on costae and at intersection of rugae and costae on visceral disc. Fine delicate spines on brachial valve.

Pedicle valve fairly evenly and strongly convex in lateral profile with most curvature in umbonal region. Anterior profile high, nearly flat-topped dome with steep sides. Umbonal region moderately inflated, protruding short distance posterior to hinge. Sulcus originating on visceral disc, shallow and indistinct, scarcely visible in some specimens. Median region strongly swollen; flanks moderately swollen.

Brachial valve moderately concave with steep sides and anterior; umbonal region broad, shallow depression; ears flatly concave and well demarcated by oblique swelling; fold low, originating just posterior to midvalve, low and inconspicuous.

Pedicle valve interior with narrow and strongly thickened adductor field and widely flabellate diductor scars. Ridge on outside of diductors strong but narrow. Ginglymus small.

Brachial valve interior with short, looped lateral ridges uniting with cardinal process to form prominent platform; cardinal process large and strongly trilobed. Adductor field not thickened but strongly dendritic. Brachial ridges well developed. Anterior of visceral disc region marked by thick granules.

MEASUREMENTS (in mm).—From locality USNM 703a, specimens 148840a (holotype) and b, respectively: length 42.2, ?, brachial valve length 30.0, 37.4; surface length 81.0, (?); hinge width 54.0, 52.8; midwidth 45.1, 47.0\*; height 26.2, (?); thickness unmeasurable.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 702c, 703a.

DIAGNOSIS.—Small, compact *Peniculauris* with exceptionally long halteroid spines on the ears.

TYPES.—Holotype: USNM 148840a. Figured paratypes: USNM 148839a, 148840b, 153997. Measured paratype: USNM 148840b.

COMPARISON.—This species is readily distinguished from any other Glass Mountains species and from *P. bassi* (McKee) by its small size and quadrate form; its length and midwidth are almost the same.

DISCUSSION.—This species is uncommon, and few complete or perfect specimens have been found. A few young specimens are of interest as they show that the brush of halteroid spines appears in adulthood rather than early in life. A pedicle valve of about 25 mm long, and about the same width, possesses curved body spines about 12.5 mm long that are given out at such a low angle that they are almost parallel to the valve surface. The ear spines on this specimen are equally slender but they are not bunched into a brush as they are on the adult.

A brachial valve 9 mm long by 12 mm wide shows only a trace of the brevisseptum, and its cardinal process is small, scarcely lobed, but deeply indented; in posterior view the cardinal process is bilobed. Another larger specimen, 14 mm long by 21 mm wide, has strongly looped lateral ridges strengthening the cardinal process, which is deeply concave in ventral view, and the process is further strengthened by a median thickening anterior to it; in posterior view the process is bilobed.

***Peniculauris subcostata* (R. E. King)**

PLATE 246: FIGURES 15-19; PLATE 394: FIGURES 1-12; PLATE 395: FIGURES 1-10; PLATE 396: FIGURES 1-10; PLATE 397: FIGURES 1-8; PLATE 398: FIGURES 1-11

*Aulosteges subcostatus* R. E. King, 1931:94, pl. 25: figs. 5-7. *Productus ivesi* R. E. King (not Newberry), 1931:69, pl. 12: figs. 1-6.

*Peniculauris mckeei* Muir-Wood and Cooper, 1960:280, pl. 100: figs. 1-7; pl. 101: figs. 1-3.

Large, thick-shelled, generally transversely rectangular in outline tending to become less transverse in adults; hinge forming greatest width; ears

extended and rounded. Sides gently convex; anterior margin broadly rounded. Spines numerous; in dense brush of delicate halteroid spines, attaining length of at least 60 mm; numerous short body spines arising from costae on visceral disc and trail. Visceral disc marked by fine costae and concentric wrinkles, strongest on posterior margin and lateral slopes which cancellate radial costae to form ill-defined reticulate pattern. Trail marked by fine costae separated by equally wide interspaces, about four or five in 10 mm on midtrail, not strongly diminishing in size anteriorly. Brachial valve with finely reticulate visceral disc of more regular pattern than that of pedicle valve; surface with numerous dimples corresponding to pedicle valve spines; ears and entire surface provided with sparse cover of fine, delicate spines.

Pedicle valve strongly convex in lateral profile, convexity greatest in posterior half; anterior profile high, steep-sided dome. Beak incurved over hinge; umbonal region narrowly swollen but expanding rapidly into visceral disc; umbonal region protruding slightly posterior to hinge; umbonal slope short but steep. Median region strongly inflated. Sulcus variable, originating on anterior side of umbonal region in some, but on visceral disc in

other specimens; sulcus shallow, narrow, or scarcely distinguishable. Flanks gently rounded and steep-sided.

Brachial valve deeply and fairly evenly concave; deepest near midvalve; sides and anterior very steep; ears well demarcated and separated by strong ridge from visceral region.

Pedicle valve interior with broad and thick adductor platform with two sets of strongly dendritic muscles, anterior pair smaller. Diductor muscle scars strongly striated longitudinally, scar large and obliquely oval. Ears deeply concave. Inner lateral slopes marked by thick ridge overhanging diductor scars. Interior surface strongly granulose.

Brachial valve interior with moderate geniculation at about right angle; cardinal process large, strongly trilobed, with myophore in old shells rotated so as to face dorsally; brevisseptum strong, often greatly thickened distally and extended posteriorly as support to cardinal process. Adductor field large, not greatly thickened, but muscle scars, both sets, strongly dendritic. Brachial ridges strongly developed and with thickened rims. Visceral disc with thickened anterior rim; interior surface pitted and strongly and irregularly granulose or with ropy surface.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702							
123445	55.9	44.0	107.0	70.3	66.7	44.4	18.3
(holotype of <i>P. mckeei</i> )							
123446a	59.3	40.4	134.0	71.4	56.0?	41.6	18.1
USNM 702un							
123446c=	58.8	41.2	123.0	67.3	52.6	38.4	24.2
152753							
USNM 702-low							
148786a	57.2	42.1	114.0	72.0*	62.6	37.8	19.5
148786b	50.6	?	110.0	67.3	49.3	33.9	?
USNM 703b							
148791	56.4	?	112.0	77.6	60.4	39.4	?
USNM 724i							
152754a	66.5	41.0	140.0	76.8	65.3	47.5	?
152754b	63.6	43.0	131.0	78.4	60.0	43.5	?

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain and Road Canyon formations.

LOCALITIES.—Cathedral Mountain: AMNH 500H; King 123; USNM 702, 702a, 702b, 702-low,

702un, 703a<sup>1</sup>, 703b, 703bs, 707q, 711q, 712o, 717g, 721u, 723k, 723p, 724i, 724s, 726o, 726u, 726y, 727x, 732u, 735b, 735g, 737f, 737s. Road Canyon: USNM 702c, 721r, 726z.

**DIAGNOSIS.**—Large *Peniculauris*, usually with elongate to quadrate body, numerous crowded costellae, and deep sulcus.

**TYPES.**—*Aulosteges subcostatus* R. E. King: holotype YPM 11837; figured paratypes T10155, T10155 a, b. *Peniculauris mckeei* Muir-Wood and Cooper: holotype USNM 123445; figured paratypes USNM 123446a, c, d; paratypes USNM 123446b. *Peniculauris subcostata* (R. E. King): figured hypotypes USNM 148785, 148789, 148791, 148802a, 148807, 148809, 148810, 152575, 153754b, c, 153993, 153994a, b; measured types: 123445; 123446a, c; 148786a, b; 148791; 152754a, b.

It was a surprise in studying the R. E. King types preserved in the Peabody Museum, Yale University, to discover that his species *Aulosteges subcostatus* actually belongs to the brachiopod species Muir-Wood and Cooper described as *Peniculauris mckeei*. That the identification of the King fragments with this species is correct is shown by the fact that *Peniculauris* is common at King's locality 123 and the stratigraphic level of this locality is prolific for *Peniculauris mckeei*. Consequently, adjustments of nomenclature are necessary.

King's species is represented by a holotype and three paratypes. The holotype is YPM 11837 and a paratype exists in the same lot. The paratype is a fragment of a pedicle valve showing a smooth shell marked by strong nodes that bore strong erect spines.

Two other paratypes belong to the University of Texas, the lot of two specimens numbered T 10155. One of these is a small pedicle valve interior showing the interarea (or ginglymus). The other is a larger specimen showing the same feature and the pedicle exterior, too poorly figured to show any details.

King's description of the holotype and other specimens goes too far because the specimens are not complete. The holotype is only a fragment of a pedicle valve with a fragment of the brachial valve attached. The brachial valve is so decorticated that it is impossible to tell what the ornamentation was. The supposed interarea looks like a ginglymus, rather than an interarea. The delthyrium is wide and triangular without any trace of cover and is thus quite unlike any of the aulostegid tribe.

The larger of the Texas specimens has the sup-

posed interarea (ginglymus) well shown. This is short but wide but there is no delthyrium, as such, dividing the structure. Just under the beak a small pit appears, produced by a down bending of the interarea. This pit must have been the socket in which the cardinal process revolved in opening and closing the valves. Anterior to the interarea in this specimen the shell is much thickened on each side of the "delthyrium." Spines on the exterior were borne on long spine ridges and the spines were in rows but not regularly placed.

These specimens are interpreted by us as fragmentary pedicle valves of *Peniculauris subcostata* displaying the ginglymus. King's specimens are from his locality 123 in the Cathedral Mountain Formation where *Peniculauris* is common.

The specimen designated as type by Muir-Wood and Cooper (1960) varies from the majority of specimens in not having as strong a sulcus. It is a young adult in which the trail has not reached its full development. The late adult stage of the species is best seen in specimen USNM 152754a which has a completely developed trail with its strongly squamose surface.

### *Peniculauris transversa*, new species

PLATE 403: FIGURES 1-12; PLATE 404: FIGURES 1-10; PLATE 405: FIGURES 1-11; PLATE 406: FIGURES 10, 11

Large, transversely rectangular in outline, hinge widest part; sides gently rounded and sloping medially; anterior margin broadly rounded. Ears large, not greatly protruding. Surface semireticulate and costate; costae slender, about five per 10 mm on trail and separated by striae about as wide as costae. Posterior half of pedicle valve coarsely reticulate but visceral region of brachial valve more distinctly and evenly reticulated. Spines numerous, consisting of brush of stout, halteroid spines on ears and base of lateral slopes; fine, short body spines in rows on costae.

Pedicle valve moderately and fairly evenly convex in lateral profile, posterior half somewhat less convex; anterior profile broad and high dome with steep sides and median region gently depressed. Umbonal region broadly and flatly convex, protruding slightly posterior to hinge. Median region strongly swollen. Sulcus originating on umbonal region, broad, shallow, and extending to anterior

margin. Flanks broadly rounded. Sides anterior to ears not indented.

Brachial valve fairly regularly reticulate, gently concave in visceral disc region, more deeply concave at place of geniculation; sides and anterior steep. Ears fairly well demarcated, forming shallow concavity. Umbonal region gently, broadly concave.

Pedicle valve interior without thickened adductor platform and with widely flabellate diductor scars.

Brachial valve interior with stout, sessile, bilobed cardinal process, moderately developed lateral ridges, and unthickened adductor field. Brachial ridges not well developed.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702c							
148835a	55.0	45.4	96.0	86.0	77.8	38.3	13.9
(holotype)							
148835c	51.4	43.6	90.0	75.0*?	66.9	26.6	9.7
148835d	49.6	39.3	88.0	68.8	61.0	28.7	13.5
148835e	34.8	30.6	45.0	37.0	48.8	11.3	6.2
USNM 721o							
148837a	46.8	37.3	90.0	74.9	70.0	31.9	13.7
148837f	52.3?	42.2	108.0	79.4	66.9	34.3?	14.9

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 702c, 719x, 721o, 721s, 721x.

DIAGNOSIS.—Large *Peniculauris* with strongly transverse body shell.

COMPARISONS.—This species differs from all others in the Glass Mountains and *P. bassi* (McKee) in having a strongly transverse body.

TYPES.—Holotype: USNM 148835a. Figured paratypes: USNM 148835b-f; 148837b, e; 153996. Measured paratypes: USNM 148835c-e; 148837a, f. Unfigured paratypes: USNM 148837a, c, d.

DISCUSSION.—A few young specimens reveal details of the brachial valve interior. A specimen 15.5 mm long by 23 mm wide shows only a slight development of the lateral ridges. The cardinal process is small but deeply indented ventrally and the myophore is trilobed posteriorly. Exterior spines are strong and numerous.

*Peniculauris transversa* is a thin-shelled species, so fragile in the etched condition that it is difficult to recover specimens from the debris, especially if it has been allowed to pile up.

#### *Peniculauris* species 1

Large, transversely rectangular outline, greatest width at hinge; sides rounded and sloping medially; anterior margin broadly rounded. Surface

semireticulate, reticulation strong and coarse on lateral slopes but less well defined on visceral disc region. Trail strongly costate, costae fairly broad and rounded, separated by spaces of lesser width than costae, numbering about four per 10 mm at front margin. Spines in dense brush on ears, and scattered short fine ones on costae.

Pedicle valve broadly and moderately curved in lateral profile; broadly domed and with steeply sloping sides in anterior profile. Sulcus originating on umbonal region, narrow and fairly deep to front margin; flanks broadly rounded. Ears large and moderately convex.

Brachial valve flatly concave in visceral region, steeply sloping sides and anterior; fold originating posterior to midvalve, subcarinate but broad and low.

Described and measured specimens: USNM 148817, 148827.

MEASUREMENTS (in mm).—From locality USNM 711d, specimen 148827, and from 715p, specimen 148817, respectively: length 61.4+, 51.0; brachial valve length 48.2?, (?); surface length 100+, 100; hinge width 94.6\*, 65.0; midwidth 85.0\*, 60.0; height 38.2+, 31.4; thickness 25.5, (?).

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch, Poplar Tank, Sullivan Peak, and Dugout Mountain members).



LOCALITIES.—Decie Ranch: USNM 707a, 707b, 707-l, 714t. Sullivan Peak: USNM 708e, 710y, 715p, 722h, 722-l, 727a. Skinner Ranch (base): USNM 711d. Skinner Ranch (top): USNM 722m. Skinner Ranch: USNM 731i. Dugout Mountain: USNM 700o, 700r.

COMPARISONS.—This species is of about the same size as the largest known specimen of *P. costata*, new species, and like that species it is strongly costate. It differs in having a somewhat less curved lateral profile, less prominent and less swollen ear, stronger and more crowded costae on the trail, and a denser brush of spines on the ears, as indicated by the crowded spine bases.

### Subfamily HORRIDONIINAE Muir-Wood and Cooper, 1960

Dictyoclostidae mostly with smooth surface; pedicle valve with posterior spine rows and few scattered body spines; brachial valve with large halteroid spines along posterior margin and ears; adductor scars dendritic.

Genus in West Texas: *Horridonia* Chao, 1927.

Authentication of *Horridonia* in West Texas is important for correlation, and demonstrates a range for this genus much farther south than heretofore expected.

### *Horridonia* Chao, 1927

*Productus* (*Horridonia*) Chao, 1927:24.—Muir-Wood and Cooper, 1960:292.—Gobbett, 1964:94.—Williams et al., 1965:H498.—Logan, 1966:163.—Nelson and Johnson, 1968:725.

*Pleurohorridonia* Dunbar, 1955, p. 89.

*Horridonia* is a well-known genus in the faunas of the Northern Permian, occurring in Europe, Greenland, Spitsbergen, Canada, and Alaska. The genus is now definitely authenticated in the Permian of the lower United States. *Productus subhorridus* Meek (1877) has long been identified as *Horridonia* but the specific name is the probable reason for its reference because this species belongs in the Paucispiniferidae. Cooper (1957a: 37) described a species called *Pleurohorridonia?* (*Horridonia*) *elongata* from the Permian of Oregon but, according to C. C. Branson (personal communication), this is related to *Productus nevadensis* Meek, which belongs to the genus *Bathymyonia*. R. E.

King described *Horridonia texana* which somewhat suggests Cooper's Oregon species and is now proved by additional specimens to be an unquestionable *Horridonia*. The genus is thus clearly and incontrovertibly a member of the Glass Mountains fauna.

### *Horridonia texana* R. E. King

PLATE 208: FIGURES 39–47; PLATE 468: FIGURES 1–4

*Horridonia texana* R. E. King, 1931:85, pl. 21: fig. 25.

Pedicle valve large and subquadrate, width slightly greater than length. Sides gently rounded, anterior broadly rounded and strongly indented by deep sulcus. Beak narrow and strongly curved over posterior margin. Umbo swollen, extending considerably beyond hinge. Posterior strongly swollen and medially marked by deep, narrow sulcus that originates near beak, deepest in posterior part, but becomes shallow and wide near anterior margin. Flanks posteriorly rounded and steep. Traces of radial costae appear in posterolateral region but most of rest of specimen shows no trace of radial or concentric markings or spines.

Brachial valve well preserved, large, with wide hinge having narrowly rounded ears. Anterior median part fairly deeply convex, marked medially by narrow, subangular median fold that originates in pit just anterior to beak. Ears flatly concave. Anterior quarter of specimen geniculated fairly sharply at angle of about 105° in dorsad direction. Ear marked by two short stout spines, one on posterior side and one at angle defining ear on anterior side.

Brachial valve with brevisseptum low and ending posteriorly between two triangular adductor patches slightly elevated and showing evidence of having been dendritically marked. Cardinal process, partly covered dorsally by platform thickening, consists of two lobes each bearing a median depression.

MEASUREMENTS (in mm).—From King locality 255 specimen YPM 11508 (holotype) and from USNM 735a specimen 154176a (hypotype), respectively: length 43.4, 29.2; surface measure 80.0+, (?); midwidth 44.8, 38.7; hinge width (?), 53.2; height 23.5?, (?).

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—King 255. USNM 703c, 735a.

DIAGNOSIS.—Deeply and narrowly sulcate *Horridonia*.



**TYPES.**—Holotype: YPM 11508. Figured hypotypes: USNM 153915a, b; 154176a.

**COMPARISON AND DISCUSSION.**—Resembles *Pleurohorridonia? elongata* Cooper but is a wider, more robust shell with a much deeper median sulcus.

The type specimen, a pedicle valve, was the only one found of this species until the present work. Another pedicle valve and two brachial valves were recovered from acid residues. The holotype is very poorly preserved in dolomite. Part of the venter, most of the lateral slopes, and most of the trail have been eroded away, leaving only the posterior third for study. This part, too, has its defects, because the shell has been altered completely to beekite, destroying nearly all details of the exterior.

The poor quality of the holotype of this species is matched by the lack of information with it. Had it not been for the lucky find of three additional specimens it would have been impossible to have authenticated the type specimen as *Horridonia*. The three additional specimens are all from the Road Canyon Formation. This leads to the suspicion, although there is no proof, that the type is also from this formation. King gives the number 255 for the locality of the holotype. This is not defined in his locality list, nor does it appear on his map. Six species are reported by King from this locality and all are Word species. According to R. E. King a specimen of the ammonite *Agathiceras girtyi* Böse appears in the matrix of the specimen. This ammonite occurs in the Word Formation. Miller and Furnish (1940:120) do not list ammonites from R. E. King's locality 255. The species is also listed from below the Word (p. 121).

Two of the new specimens are young individuals, a pedicle valve and a brachial valve. The former has the strong median sulcus of the holotype and the brachial valve has the same characteristic median fold. The clinching evidence of the affinity with *Horridonia* is the spines on the ear of the dorsal valve. *Horridonia* is especially characterized by the peculiar arrangement of spines in the brachial valve, which are generally located along the posterior margin and the ears.

The cardinal process of these Glass Mountains specimens is not characteristic of the cardinal process of the Zechstein or British *Horridonia*. Specimens from those places have a characteristic dictyoclostid type of cardinal process with a strong elevated median lobe. The Texas specimens may

be young or not fully developed, because a median lobe is not present (see Muir-Wood and Cooper 1960, pl. 108: fig. 8).

### Family PAUCISPINIFERIDAE Muir-Wood and Cooper, 1960

[Ex Paucispiniferinae Muir-Wood and Cooper, 1960]

Costate, obscurely costate, or capillate Productacea with four or more halteroid spines; sessile, dorsally recurved, trilobed cardinal process with zygidium.

Genera in West Texas: *Paucispinifera* Muir-Wood and Cooper, 1960; *Liosotella* Cooper, 1953; *Anemonaria* Cooper and Grant, 1969; and *Polymorpharia*, new genus.

The first two genera are abundant in the Road Canyon and the limestone members of the Word Formation of the Glass Mountains. They are common in the Cherry Canyon Formation of the Guadalupe Mountains. *Anemonaria* is a rare genus in the Cathedral Mountain Formation. *Polymorpharia* is an aberration of *Paucispinifera* occurring in the Word and Cherry Canyon formations.

### Genus *Anemonaria* Cooper and Grant, 1969

*Anemonaria* Cooper and Grant, 1969:8.

Medium size, subrectangular outline, hinge generally forming widest part; spineless ears laterally extended; deeply concavo-convex with thin body cavity. Anterior commissure with well-defined median dorsad wave. Beak small and incurved; delthyrium obsolete. Surface nearly smooth but trail with crowded but obscure costellae. Spines few; row on lateral slopes overhanging ears; occasional spines on trail and on visceral disc region.

Pedicle valve strongly convex in lateral profile, strongly but roundly geniculated near midvalve; visceral disc and trail regions of about equal length. Sulcus strong, U-shaped, originating near middle of visceral disc. Ears prominent but variable.

Brachial valve deeply concave, median fold best defined in anterior two-thirds.

Pedicle valve interior with widely flabellate diductors not surrounding posteriorly situated median, elongated adductor scars. Ear baffles only incipiently developed.

Brachial valve with cardinal process small, *Liosotella*-like, sessile, and without median shaft; lophidium narrow; zygidium broad as in *Paucispinifera*, brevisseptum reduced; median adductor pair elongated and somewhat thickened, lateral pair small and located in posterior position. Brachial ridges faint, laterally extended. Endospines reduced and forming single row. Interior granulose.

TYPE-SPECIES.—*Anemonaria inflata* Cooper and Grant (1969:8, pl. 5: figs. 28, 29), junior synonym of *Marginifera sublaevis* R. E. King (1931:89, pl. 23: figs. 15a-c, ?16a, b, 19, not figs. 13, 14 and 17).

DIAGNOSIS.—Nearly smooth Paucispiniferidae resembling *Kozlowskia* externally but not having a marginal ridge and with a row of spines overhanging the ears.

COMPARISON.—The resemblance of this genus to a number of the marginiferoids and especially to *Kozlowskia* Fredericks, which has long passed as *Marginifera* Waagen, has led to its previous obscurity. The most obviously similar genus is *Kozlowskia* but the differences are equally obvious when good material is obtained. *Anemonaria* externally has the nearly uncostate appearance of *Kozlowskia* and a similar paucity of spines, although the spines it does have are arranged differently from those of *Kozlowskia*. Internally the brachial valve has a zygidium and lacks the marginal ridge and the trails so conspicuous in *Kozlowskia*.

Although smaller, *Anemonaria* resembles *Spinarella*, new genus, and *Xestosia*, new genus. The spine arrangement of all three, however, precludes any possibility of generic identity. *Spinarella* is provided with a row of spines along the posterior margin, whereas *Xestosia* has an enormous brush of spines on the ears. Both are thus completely unlike *Anemonaria*.

*Liosotella* Cooper has a spine arrangement like that of *Anemonaria* but it is more strongly costate. This is true also of *Paucispinifera* Muir-Wood and Cooper. Thus *Anemonaria* by its structure suggests a nearly smooth *Liosotella*.

DISCUSSION.—The interior of the brachial valve indicates the true relationship of this genus with the Paucispiniferidae. This would not be suspected from the exterior except for the spine arrangement which is like that of *Liosotella*. The cardinal process of *Anemonaria* is small and delicate but the zygidium is broad and conspicuous. The lophidium, on

the other hand, is small and narrow. The myophore occupying the middle lobe of the cardinal process is large and closely surrounded by the lateral lobes. Other features of interest in the brachial valve are the reduction of the endospines, which appear as a curving row of strong nodes. These are supplemented by numerous elongated pustules, probably taleolae.

### *Anemonaria sublaevis* (R. E. King)

PLATE 408: FIGURES 1-26

*Marginifera sublaevis* R. E. King, 1931:89, pl. 23: figs. 15a-c, ?16a, b, 19 [not fig. 13 (= *Kozlowskia finlayensis*, new species); not fig. 14 (= *Kozlowskia kingi* Stehli); not fig. 17 (= indeterminate).]

*Anemonaria inflata* Cooper and Grant, 1969:8, pl. 5: figs. 28, 29.

Medium size, subrectangular outline, large often extended ears forming widest part. Sides gently rounded; anterior margin broadly rounded and slightly emarginated medially; anterior commissure with small dorsad wave. Beak small. Valves concavo-convex. Surface obscurely costate or costellate, ribbing strongest near margin. Halteroid spines in row overhanging usually naked ears but some specimens with occasional spines on ears; occasional spines on body and trail.

Pedicle valve strongly but unevenly convex, posterior third flattened, median third well rounded, trail gently convex. Angle of geniculation about 40°. Umbonal region swollen, umbonal slopes steep. Sulcus originating about 5 mm anterior to beak, shallow but prominent, widening anteriorly and slightly indenting anterior margin. Flanks bounding sulcus narrowly and strongly swollen, slopes steep. Anterior slope steep. Geniculation occurring about 10 mm anterior to beak.

Brachial valve with strongly concave umbonal region, concavity increasing to just beyond midvalve where geniculated. Sides and anterior steeply descending. Fold originating near midvalve, low and subcarinate, not conspicuous. Ears shallowly concave.

Pedicle valve interior with widely flabellate diductor scars and elongate adductors not enclosed by diductors. Ear baffles forming small oblique ridges, interior papillose. Ginglymus broad and flat.

Brachial valve interior with small cardinal process having broad zygidium and narrowly rounded lophidium. Median adductors slightly ele-

vated; lateral adductors indistinct. Brevisseptum reduced, reaching posteriorly only to middle part of adductors. Brachial ridges not strongly developed.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702							
YPM 11792a (lectotype)	17.6	?	32.5	22.0	23.5	11.2	?
152770a	15.3	13.0	26.0	22.3	19.4	9.4	3.7
152770b	15.5	12.3	30.0	19.5	19.9	10.1	4.3
USNM 721u							
152705a	16.9	14.0	26.0	?	22.9	11.5	4.3
152705b	16.0	12.6	27.0	23.7	20.7	9.7	5.2
152705c	15.2	12.6	27.5	20.4	21.6	9.4	4.0
152705d	15.7	?	26.0	24.5	21.9	9.2	?
152705e	17.3	?	30.0	19.5	19.9	10.1	4.3

STRATIGRAPHIC OCCURRENCE.—Bone Spring, Cathedral Mountain, and Road Canyon formations.

LOCALITIES.—Bone Spring: AMNH 678; USNM 725s. Cathedral Mountain: R. E. King 120; USNM 702, 702b, 702ent, 702un, 703b, 707q, 711q, 711w, 721r, 721u, 723p, 726o, 726v, 726y, 732u. Road Canyon: 703c.

DIAGNOSIS.—Nearly smooth *Anemonaria* with fairly deep sulcus and swollen pedicle valve.

COMPARISON.—Differs from *Paucispinifera* and *Liosotella* in its nearly smooth shell surface and the row of spines on the flanks.

TYPES.—Lectotype: YPM 11792a. Figured paratypes: YPM 11792b, T10051. Figured hypotypes: USNM 152770a, 152771a, 153838, 153839, 153883a-j. Measured hypotypes: USNM 152770a, b; 152705 a-e.

DISCUSSION.—When exposed by fracturing the rock, this species has a lustrous and flaky thin shell. In the silicified state several thin layers may be seen at the margins. All the specimens are extremely fragile and the species is not common.

King failed to select a type from the seven specimens he illustrated. From his locality 120, he designated two specimens as cotypes (1931, pl. 23: figs. 15 and 19). Of these, one must be selected as type, and we have chosen YPM 11792a because it is the best preserved of the specimens illustrated. King's lot includes a specimen (fig. 14) of *Kozlowskia kingi* Stehli, a specimen (fig. 13) of *Kozlowskia finlayensis*, new species, and an indeterminate speci-

men (fig. 19). The lectotype seems to be from our USNM 721u approximately King locality 120 as interpreted by us.

Genus *Liosotella* Cooper, 1953

*Liosotella* Cooper, 1953:26.—Dunbar, 1955:73.—Muir-Wood and Cooper, 1960:227.—Williams et al., 1965:H482.

Small to medium size; hinge wider than midwidth; well developed and usually extended ears. Deeply concavo-convex. Pedicle valve usually with strong sulcus, brachial valve with corresponding but generally poorly defined fold. Outline quadrate, length and width nearly equal, but width usually slightly greater than length. Both valves commonly strongly geniculated, usually costate; costae on umbonal and often visceral disc regions poorly developed or lacking; venter and trail commonly strongly costate. Spines variable in number but all species with curved row of spines near base of lateral slope and overhanging ear; number varying from three to seven. Occasional spines along posterior margin; stout spines, usually few in number but of considerable length, on trails; scattered smaller spines on sides, venter, and trail.

Pedicle valve interior with ear baffles present but variable; adductor field usually elevated on ridge produced by median sulcus, and generally thickened; adductor scars elongate. Diductor scars flabellate. Spines commonly extended interiorly.

Brachial valve usually with large sessile cardinal

process posteriorly trilobed; median lobe of myophore elevated. Zygidium strongly developed. Adductor field thickened, median pair lobate and smooth, outer pair small and dendritic. Brevisep-tum anteriorly extended over trail; ear baffles well formed, laterally fluted, commonly extended anteriorly and medially to form poorly defined ridge around visceral disc, reminiscent of *Marginifera*. Endospines usually well developed.

TYPE-SPECIES.—*Liosotella rugosa* Cooper (1953: 37, pl. 100: fig. 9, pl. 110: figs. 11–18).

DIAGNOSIS.—Strongly costate, squarish Paucispiniferidae.

COMPARISON.—*Liosotella* was originally placed in the Marginiferidae but the discovery of a zygidium in all of its species requires transfer to the Paucispiniferidae. *Paucispinifera* is very close to *Liosotella* and it is difficult to assign some specimens when the costae of *Liosotella* are poorly developed or when, in aberrations of *Paucispinifera*, the costae are stronger than normal. Generally the combination of strong costae and nearly square outline will establish *Liosotella*. Inasmuch as the zygidium is, so far as known, confined to this family, no further comparison is necessary.

DISCUSSION.—When Muir-Wood and Cooper (1960) redefined *Liosotella*, an imperfect brachial valve was illustrated. This specimen was damaged, in that its zygidium had been destroyed, and this important feature was overlooked. Later collecting, especially in the younger parts of the Word Formation resulted in the accumulation of fine material showing the zygidium and other features to perfection. Now the details of the brachial valve are clearly known. Moreover, development of some of the material from Sonora, Mexico, demonstrated the presence of a zygidium in the type species. The internal features of *Liosotella* are identical to those of *Paucispinifera* which are described in detail under that genus and do not need to be repeated.

We have not found *Liosotella* in the Cathedral Mountain Formation, although *Paucispinifera* has been seen there rarely. *Liosotella* thus seems to be confined to the Road Canyon Formation and the Guadalupian. It is abundant in the various limestones of the Word Formation in the Glass Mountains and is apparently scattered in occurrence in the Delaware Mountain Formation, which is not yet well known. The Bell Canyon Formation and its equivalents in the Capitan Formation contain

*Liosotella*, but it is not as abundant as it is in the Word. It is also a relatively rare fossil in the Cherry Canyon Formation.

### *Liosotella costata*, new species

PLATE 409: FIGURES 1–56; PLATE 410: FIGURES 14–49

Small, subrectangular to subsemicircular outline; hinge usually forming widest part; ears prominent, usually extended laterally; sides gently rounded, sloping toward midvalve; anterior margin broadly rounded and indented medially. Surface strongly costate, costae most prominent on venter and fold, about three costae in 5 mm on venter, posterior third obscurely costate to nearly smooth. Spines long and slender, consisting of one spine on ear; row of three spines near base of lateral slope, last and outermost being largest; and one or more spines on trail on each side of sulcus about midway between anterior margin and venter. Longest observed spine 15 mm.

Pedicle valve narrowly convex in lateral profile, visceral disc or posterior portion flattened, but trail moderately convex. Anterior profile strongly domed and having lobate posterior margin, deeply indented by sulcus, and with narrowly rounded flanks. Beak small, umbonal region gently swollen with short slopes. Sulcus originating about midway between beak and venter, deep and generally V-shaped, narrowing somewhat anteriorly. Flanks with precipitous lateral slopes. Ears variable, usually convex, pointed, triangular to broadly rounded or truncated.

Brachial valve moderately deep, deepest at angle of geniculation; umbonal region forming deep depression extending to midvalve; ears gently concave, well demarcated. Fold originating at midvalve narrowly rounded to sharply carinate, usually prominent. Trail long and steep.

Pedicle valve interior with prominent ear baffle forming ridge posterolaterally and extending nearly to beak; ear baffle not extending anteriorly as marginal ridge. Adductor platform narrow, uniting with median ridge formed by sulcus of exterior to form long continuous ridge; inner adductor pair located on platform, outer scars on each side of platform. Diductor scars small and subcircular. Surface anterior to muscle field and inside ear baffles strongly granulose to endospinose.

Brachial valve interior with strong lateral ridges joining strong ear baffles and then extending as submarginal ridge around visceral disc area. Cardinal process small and rounded, with median lobe drawn posteriorly; zygidium well developed. Ad-

ductor field not greatly thickened; scars elongate. Brevisseptum slender, elevated anteriorly. Brachial ridges well developed. Ear surface granulose. Endospines large, in one or more rows overhanging line of geniculation.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 707e							
149577a	17.0	13.7	27.5	28.2	21.9	10.4	3.9
149577b	17.8	13.2	33.0	27.0	22.7	12.4	5.0
149577c	16.0	12.5	30.0	25.0	20.8	11.7	5.7
149577d	14.9	12.3	28.0	27.4?	19.3	10.6	4.6
149577e	15.0	11.8	25.0	21.4	18.8	9.6	4.0
149577f	13.4	11.0	23.0	23.8	16.8	9.7	4.2
149577g	13.5	10.7	22.5	24.1	17.8	8.7	3.9
149577h	12.5	10.0	19.5	19.1	13.8	7.7	1.7
149577i	12.5	10.2	19.0	18.4?	16.9	6.5	2.0
149578	16.6	13.0	32.0	27.7	22.0	11.4	3.7
(holotype)							
149577j	12.0	9.6	17.0	16.8?	15.9	6.5	1.1
149577k	11.7	10.2	15.5	14.9	14.7	4.0	0.5
149577l	10.8	9.7	14.0	13.5	15.0	4.0	0.6
149588m	10.2	9.6	12.5	11.4	12.7	3.1	0.8
149577n	8.6	8.2	10.5	11.1	10.8	2.6	0.6
149577o	15.4	12.3	25.5	21.5	17.9	10.2	6.0
149577p	16.5	12.8	30.0	25.3	20.0	11.0	4.0
149577q	13.2	10.3	26.0	21.5	18.3	9.6	3.8
149577r	14.3	12.2	21.5	24.4?	16.2	8.8	1.7
149577s	12.5	10.9	16.0	15.0	15.5	5.0	1.1
149577t	13.4	11.4	23.0	19.7	17.3	8.9	4.0
149577u	14.4	11.3	26.0	24.4	19.2	10.5	5.8
149577v	16.7	13.6	29.0	26.1	10.6	10.6	3.7
149577w	15.2	?	29.0	24.5	19.2	10.7	?
149577x	13.3	11.4	20.0	19.2?	17.6	7.3	1.7
149577y	17.6	15.0	27.0	26.6?	25.8	9.7	2.2
149577z	11.7	10.7	20.0	17.0	15.7	6.8	2.6
149577aa	16.0	12.8	30.0	28.2	24.0	11.3	4.5
149577bb	16.2	12.0	29.0	23.4	18.0	10.7	6.4

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation, Cibolo Formation (thin-bedded Zone of Udden).

LOCALITIES.—Road Canyon: AMNH 509; USNM 707e, 716x, 721j, 721x, 721y, 722g, 723x, 724a, 724c, 726d, 732j, 736x, 737q. Cibolo: 738-l.

DIAGNOSIS.—Small, transverse, strongly costate *Liosotella*.

TYPES.—Holotype: USNM 149578. Figured paratypes: USNM 149576a, b, d-i; 153945a-n; 153946a-e; 153947a, b; 153948. Measured paratypes: USNM

149577a-z, aa, bb. Unfigured paratypes: USNM 149576c, g.

COMPARISONS.—This is a small species that compares chiefly with *Paucispinifera sulcata*, new species, from the Road Canyon Formation; it is readily distinguished from the latter, however, by its larger size, its less strong costae, and the generally wider fold. Inasmuch as *L. costata* is one of the most regularly ornamented species of the genus it will not be confused with any other species. It differs from *L. wordensis* (King) in its greater width.



**DISCUSSION.**—Although *L. costata* can be easily distinguished from *Paucispinifera sulcata*, it is interesting to note that species of different genera share some features in common. The degree of variation, especially that of the costae, is the same in the two species.

**INTERIOR CHARACTERS.**—A few characters of the interior of both valves are worthy of remark. In the pedicle valve the ear baffle is extended posteromedially as a ridge. On the outside of this ridge on the portion of the ear that narrows toward midvalve, the surface is strongly but irregularly pitted. These pits have their counterpart in the opposite valve as coarse granules on the outside of the ear baffle.

The adductor platform is triangular and completely occupied by the elongate inner scars of the adductor set, each of which is divisible into two tear-shaped scars, the outer scar in a deep, elongate trough on each side of the platform. The median part of the valve is marked by a carinate median ridge which is a reflection of the sulcus of the exterior. The adductor platform is continuous with this ridge. The ridge anterior to the platform and the inner walls of the shell just ventral to the ear baffles are strongly granulose or endospinose. The interior floor of the valve, anterior to the muscles and on each side of the median ridge, is marked by pustules finer than the lateral ones.

The spines of the exterior appear on the interior as small holes, rounded or circular in the case of newly formed spines, but forming a narrow slit in the older spines. The spine openings in this species are thus closed in the same manner as in other productids.

The brachial valve of this species is basically like that of other species of *Liosotella* but the subperipheral or marginiferoid ridge is somewhat better developed. This extends from the ear baffle around the inside margin to unite medially on the trail slope below the ridge of endospines.

Other structures of the interior add no features new to the genus. The cardinal process shows the same types of variation and development as those seen in *Paucispinifera*. The inner adductor scars are divisible into two scars for each half, although their bilobed nature is not always readily apparent.

**VARIATION.**—Variation occurs in the form, ornamentation, sulcus, and spines. The hinge and ears are the most variable parts that affect the shape. Most specimens are transverse but a few tend to-

ward squareness. The ears are generally large and extended in the adult but young specimens tend to have small and acutely angular ears. Most specimens are strongly costate, but finer costae appear in the sulcus of many and a few appear to be costellate, so numerous are the ribs. Specimens with a broad sulcus tend to have somewhat finer costae than the ones with a narrow and deep sulcus.

**GROWTH.**—The smallest specimen of this species is 2 mm long by 2.5 mm wide. It has a spine on each side of the beak and indications of short attachment spines on the umbo. It also preserves the first spine of the row at the base of the lateral slopes.

The umbo is flattened, indicating attachment to or pressure against a hard surface. Several other small specimens having a length of 4 to 5 mm show the same features. All have flattened umbones and small attachment spine stubs. On these the second spine of the row at the base of the lateral slopes has just formed on the edge of the shell. The third spine in the series appears between 8 and 10 mm of length. Ears appear at about 9 to 10 mm but in shells of this length the hinge is still narrower than maximum width. This is about the size at which adult characters begin to form, i.e., geniculation begins, ears form, and the hinge begins to widen.

### *Liosotella irregularis*, new species

PLATE 415: FIGURES 1-35

*Marginifera popei* R. E. King (not Shumard, 1859), 1931:88, pl. 22: figs. 17-19 [not 16].

Medium size for genus, generally wider than long and somewhat rectangular in outline. Hinge generally forming greatest width. Sides gently rounded; anterior margin fairly strongly rounded and indented medially. Ears large, acute in young, generally bluntly pointed in adults. Surface strongly but irregularly costate. Umbonal region nearly smooth, but visceral disc, venter, and trail strongly costate, especially on trail. Costae numbering two to three per 5 mm. Spines long, strong, and stout; curved row of four spines low on lateral slopes; two to several large spines on trail; and few short spines on umbonal region and visceral disc.

Pedicle valve fairly evenly convex in lateral profile, venter strongly curved but posterior third shorter and more strongly curved than trail; anterior profile high dome with nearly straight sides

but indented top. Umbonal region fairly strongly swollen, slopes steep. Sulcus originating just anterior to nearly smooth umbonal region, broadly to narrowly U-shaped and extending to anterior margin. Flanks bounding sulcus narrowly rounded, sides precipitous.

Brachial valve deeply concave, greatest depth at midvalve; trail and sides steep; fold low, narrowly rounded, and originating posterior to midvalve, just anterior to umbonal depression. Ears well demarcated and concave.

Pedicle valve interior with ears flattened and

baffles overhanging lateral valve walls; adductor platform greatly thickened and expanded anteriorly. Diductor scars opposite anterior end of platform, transversely and narrowly elliptical. Spine extensions commonly prominent.

Brachial valve interior with trail strongly costate and minutely pustulose; adductor platform small, well thickened; cardinal process generally small; endospines long and stout in one to several rows. Brevisseptum delicate; ear baffles small, delicate, forming obscure ridge anteriorly. Lateral ridges not developed. Brachial ridges not strongly thickened.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 715i							
149583a	25.9	?	48.0	31.8	28.8	15.4	?
149583b	22.3	?	44.0	26.1	24.3	14.3	?
149583d	25.1	16.4	48.0	30.8	25.0	15.3	5.5
(holotype)							
149583e	20.9	?	40.5	26.0	23.0	14.0	?
149583f	20.7	?	40.0	25.6	24.0	14.3	?
149583g	21.0	16.6	42.0	?	21.9	14.2	7.0
149583h	20.2	15.0	41.5	26.2	23.6	13.8	5.0
149583i	18.4	?	31.5	21.6	20.7	11.4	?
149583j	18.3	?	35.5	21.4	21.1	12.5	?
149583k	16.7	14.7	24.0	24.0	21.3	8.0	2.2
149583l	16.4	?	24.0	20.9	20.5	7.5	?
149583m	16.7	?	22.0	13.7?	18.8	6.1	?
149583n	14.0	?	20.0	12.6	16.9	6.3	?
149583o	8.3	?	12.0	?	10.2	3.7	?

STRATIGRAPHIC OCCURRENCE.—Word Formation (Appel Ranch Member).

LOCALITIES.—USNM 704, 706d, 714o, 715i, 719z, 722t, 727j, 731z, 737b, 737w, 741p, 742b.

DIAGNOSIS.—Strongly costate *Liosotella* with spine umbonal region and with length less than the width in the adult.

TYPES.—Holotype: USNM 149583d. Figured paratypes: USNM 149583c, p; 151601a, b, e; 153939a–e; 153940a, b; 153941a, b. Measured paratypes: USNM 149583a, b, e–o. Unfigured paratypes: USNM 149583a, b, e–o.

COMPARISONS.—*Liosotella irregularis* is fairly large and quadrate, but it is the strongest ribbed Glass Mountains *Liosotella* so far found. This feature distinguishes it from *L. spinumbona*, new species, from the Guadalupe Mountains. It suggests

*L. magnirugosa* Cooper from Mexico, but is less regularly marked with unequal costae, and is much less umbonate than the Mexican species. The Glass Mountains species appears to attain a larger size than *L. grandicosta* Dunbar from Greenland, but that species is more strongly costate, especially in its extreme forms. The Texas species has a more swollen umbonal region, especially in lateral profile.

DISCUSSION.—Although the ear baffle of this species is not exceptionally large, the striation of the lateral wall just ventral to the baffle is strong and prominent and fairly long, and the spines are sealed first by narrowing the orifice to a slit. The diductor scars are fairly small and narrowly elliptical, with a broad area of callus posterior to them. The adductor platform is very wide, and the muscles on it

have the teardrop shape and bilobed form of the inner pairs. The outside lateral muscles are deeply sunk and dendritic.

The brachial valve of this species is not strongly thickened. The largest and oldest shells are not strongly thickened, but some of them show the overlap of the visceral disc region on the slope of the trail. In specimens in which the thickening has not yet proceeded to a great extent, the end of the visceral disc appears as a marginiferid ridge continuous with the ear baffles. Strainer spines are sparse but large in this species. The cardinal process, as in all these species, is variable.

The only significant feature of the young is the abundance of umbonal spines on the pedicle valve. These are conspicuous in some specimens. Growth appears to be like that of most of the Paucispini-feridae.

*Liosotella opima* (Girty)

PLATE 416: FIGURES 1-25

*Productus popei* var. *opimus* Girty, 1909:258, pl. 20: figs. 12-14a. [Not *Marginifera opima* (Girty) King, 1931:87, pl. 22: figs. 20, 22, 23 (= *Paucispinifera auriculata*, new species); not figs. 21, 24, 25 (= *P. quadrata*, new species).]  
*Productus popei* Girty (not Shumard), 1909:257, pl. 20: figs. 9-11b.

Medium size for genus, transversely rectangular outline; sides rounded; anterior margin broadly rounded and medially indented. Umbo protruding

only slightly posterior to hinge; beak small; surface costate, umbonal region, and posterior part of visceral disc smooth or nearly so; costae best developed on venter and trail, crowded, numbering about twenty, one or two occupying sulcus. Spines numerous; few small ones along posterior margin; curved row of six spines on slopes and overhanging ears; scattered fairly large spines on trail; smaller spines on venter and visceral disc.

Pedicle valve narrowly but unequally convex in lateral profile, visceral disc region much flattened, venter abruptly and narrowly rounded, trail moderately convex; anterior profile moderately high dome with indented median and steeply sloping sides. Visceral disc gently convex, with gentle lateral slopes. Sulcus originating just anterior to beak, narrow and deep, front margin strongly indenting. Flanks rounded and with precipitous sides.

Brachial valve with moderately deep median region and deep umbonal depression; ears deflected, flatly convex and set off by low, oblique fold. Sides and anterior moderately steep.

Pedicle valve interior with prominent, strongly elevated adductor field and flabellate diductor scars, ear baffles strong, fluted on inside surface.

Brachial valve interior with cardinal process varying from narrow to bulbous in specimens of same size, sessile, trilobed in posterior face; zygidium well formed, narrow; brevisseptum low, anteriorly extended; adductor field with inner scar pair lobate and outer scars small and dendritic. Ear baffles slightly developed. Endospines short, slender.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USGS 2930							
118524a	17.3	?	27.0?	?	24.6	7.9	?
(lectotype)							
118524b	18.4	?	29.0?	32.0*	26.0	9.5?	?
118523a	15.8	?	28.0?	25.0*	21.5	8.6	?
USNM 731							
152755a	18.7	?	40.0	33.0*	25.8	13.7	?
152755b	18.0	14.2	38.0	31.6	23.6	13.5	8.9
152755c	15.8	13.8	23.5	17.0	21.9	9.1	4.5
152755d	16.7	14.1	28.5	18.0*?	20.0	10.5	6.3
AMNH 635							
152756a	16.4	13.8	29.0	24.2	23.2	11.2	5.1
152756b	15.9	13.1	29.0	23.8	21.6	10.8	4.7

**STRATIGRAPHIC OCCURRENCE.**—Bell Canyon Formation (Hegler and Pinery members).

**LOCALITIES.**—Pinery: USGS 2930 (green). Hegler: AMNH 635; USNM 731, 732a.

**DIAGNOSIS.**—Transverse, fairly strongly costate *Liosotella* with very flattened umbonal region and visceral disc.

**TYPES.**—Lectotype: USNM 118524a. Paratypes: USNM 118524b, c. Figured hypotypes: USNM 152765d–f; 152766a, b. Measured paratypes: USNM 118523a; 118524b. Measured hypotypes: USNM 152755a–d; 152756a, b.

**COMPARISON.**—This species is most like *L. popei* (Shumard); indeed, Girty (1909) expressed some misgivings about naming the variety *opima*. Nevertheless, although the two are very close, they appear not to be the same and may also have a different stratigraphic occurrence, although we are not certain on this point. *Liosotella opima* is definitely wider and has a much flatter visceral region than that of *L. popei*. When viewed from the dorsal side, the visceral region rises only slightly beyond the hinge, whereas in the same view, *L. popei* is moderately domed.

**DISCUSSION.**—We have placed the specimens identified by Girty as *Productus popei* in the synonymy of *L. opima* because they seem to be young examples of that species rather than referable to Shumard's species. Furthermore, they come from the same locality and same type of rock as Girty's variety. Girty's specimens are badly exfoliated, and this gives the impression that the costae are narrower and more distant than they really are. The lectotype (USNM 118524a) preserves some of the original shell along the anterior margin, and this shows the costae to be much wider and less convex than the fillings of the interior. Girty's specimens, however, share in common with our silicified ones the very flattened umbonal and visceral regions that are a specific character of this species.

Girty's type lot of *L. popei* var. *opima* consists of three specimens, all decorticated and damaged in one way or another. There are two pedicle valves and the impression of a brachial valve with some shell remnants adhering. These have the status of cotypes. To fix the species we select USNM 118524a as lectotype. This specimen has traces of the outside shell and is the least crushed of the three. Unfortunately the ears are not preserved in

their entirety. In spite of these deficiencies it is the best specimen.

We have placed in this species about 50 specimens, from the Hegler Member of the Bell Canyon Formation, which conform to the type. These indicate the species is variable, with costae ranging in number from ten on each side of the sulcus, as in the lectotype, to as few as six on each side. These costae bifurcate on the venter, and internally the troughs representing the costae are narrower than the external costae. All the silicified specimens have very flattened visceral regions. The value of the silicified specimens is the internal details that they reveal.

The pedicle valve has a fairly thickened adductor region and strong ear baffles. The cardinal process is variable; some specimens having a narrow and delicate cardinal process but others of the same size have a stout and bulbous one. The zygidium is well developed. Another feature of interest is the anterior bilobation of the median pair of adductor scars in the brachial valve. Each lobe is somewhat tear-shaped, the narrow ends meeting posteriorly to produce a triangular scar with one side lobate. In some specimens the outer adductor scar is small and strongly dendritic and well thickened.

### *Liosotella parva*, new species

PLATE 416: FIGURES 26–54

Small for genus, length and midwidth about equal in adults; subrectangular outline; hinge usually wider than midwidth; ears large, acute to bluntly pointed, sides gently rounded; anterior margin somewhat narrowly rounded and indented medially. Surface costellate on venter and trail but nearly smooth on visceral disc and umbonal region; costae 3 or 4 per 5 mm on trail. Halteroid spines long and stout; in curved row of five near base of lateral slopes; 2 or more on trail, basic two usually near midtrail and on opposite sides of sulcus; numerous small spines on umbonal and visceral regions.

Pedicle valve in lateral profile with venter narrowly rounded, posterior third somewhat flattened, trail long and gently curved. Anterior profile steep-sided dome with deeply indented top. Beak small; umbonal region moderately inflated with moderately steep slopes to ears; sulcus originating about

midway on visceral disc, usually deep and narrowly U-shaped but variable. Flanks bounding sulcus narrowly rounded.

Brachial valve deeply and fairly evenly concave, deepest medially; umbonal region smooth depressed area extending to midvalve; fold originating at midvalve, low, subcarinate. Sides and trail moderately steep; ears concave, defined by oblique, inconspicuous ridge or slope change.

Pedicle valve interior with ear baffles forming small shelf and extending as ridge to delthyrium;

adductor platform narrow and elongate and strongly thickened in adults; submarginal ridge indistinct.

Brachial valve interior with lateral ridges variably developed and, when present, uniting with low ear baffles and then extending anteriorly and medially as rim around trail; cardinal process small and with well-formed zygidium; adductor field elongate, moderately thickened; brachial ridges well formed; endospines small, forming band at edge of visceral disc.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706c							
149589a	18.4	?	36.0	21.9	21.3	12.8	?
149589b	18.8	12.8	37.0	21.2	19.4	12.7	4.1?
149589c	17.4	13.1	30.0	21.6	20.0	10.6	3.7
149588d	17.4	?	34.0	19.7	18.5	11.6	?
149589e	15.8	11.9	28.0	19.2	17.8	9.4?	3.4
149589f	15.9	12.7	29.0?	18.2	18.0	9.2	4.1
149589g	15.7	12.2	29.0	17.8	18.5	10.0	3.9
(holotype)							
149589h	15.2	12.3	31.4	18.2	17.0	10.8	5.0
149589i	14.4	11.0	26.5	19.0	15.3	8.9	3.0
149589j	14.3	11.1	26.0	16.9	16.0	9.0	4.0
149589k	13.7	11.2	21.5	17.5	16.0	8.2	3.3
149589l	11.5	?	20.0	14.5	12.8	6.5	?

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank and Willis Ranch members, lens between Willis Ranch and Appel Ranch members).

LOCALITIES.—China Tank: USNM 706c, 726r. Willis Ranch: 706, 706e, 723w. Lens: 706b.

DIAGNOSIS.—Small compact *Liosotella* with four spines in curved row and spinose umbonal region.

TYPES.—Holotype: USNM 149589g. Figured paratypes: USNM 149589a, f, m-o, q, r; 153951. Measured paratypes: USNM 149589a-f, h-l. Unfigured paratypes: USNM 149589b-e, h-l, p.

COMPARISONS.—This species, because of its small size is not likely to be confused with any other member of this genus except *L. wordensis* (R. E. King). However, *L. parva* is larger than *L. wordensis* and is less strongly costate. Furthermore, it has a deep and prominent sulcus, a feature not shared by the latter. The form and the outline are like those of *L. tetragonalis*, new species, but the latter is large and

solid; and the young of the two species are not to be confused because youthful *L. tetragonalis* is wider and less convex than the young of *L. parva*. *Liosotella vadosinuata* Dunbar from Greenland is a small species but it is more finely ribbed than the Texas species. *Liosotella parva* is uncommon in the China Tank Member; all the etchings from this member only produced 75 specimens. It is still more unusual from the succeeding Willis Ranch Member of the Word, which has produced but a single specimen.

DISCUSSION.—An interesting feature of the brachial valve of old specimens of this species is the presence of a distinct layering of the visceral area over the trail. In these old specimens the visceral area is greatly thickened and thus overhangs the trail. This is not like *Marginifera*, in which the thickening is marginal and ridgelike.



*Liosotella popei* (Shumard)

PLATE 412: FIGURES 1-11

*Productus popei* Shumard, 1859:290; 1860:389, pl. 11: figs. 8, 8a. [Not of Girty, 1909:257, pl. 20: figs. 9-11b; not *Marginites popei* King, 1931:88, pl. 22: figs. 16-19.]  
*Productus occidentalis* Girty (not Newberry), 1909:262, pl. 12: figs. 4-4c.

Medium size for genus; slightly wider than long; hinge wider than midwidth and produced into narrowly rounded ears. Sides gently rounded; anterior moderately indented medially. Surface irregularly costate, visceral disc region with only indistinct costae or smooth, venter and trail with 6 to 10 costae on each side of the sulcus and 1 to 3 in the sulcus; costae narrowly rounded, spaces between costae about equal in width. Spines numerous, few small ones along posterior margin, curved row at base of lateral slopes and overhanging ears, including largest spines at anterior end of row; scattered small spines on visceral disc and venter and larger scattered spines on trail.

Pedicle valve narrowly arched in lateral profile, maximum curvature at venter; anterior profile a high and narrow dome, slightly indented medially and with nearly straight sides. Visceral region with short lateral slopes and moderately swollen umbonal region moderately arched beyond hinge line. Venter strongly swollen, trail moderately convex; sulcus variable but always present, originating on anterior side of visceral disc and deepening anteriorly to margin; sulcus varying from shallow to fairly strongly deep, sufficiently deep to divide valve into conspicuous lobes. Flanks bounding sulcus swollen.

MEASUREMENTS (in mm).—Brachial valve length of USNM 151611d, 13.4; of others, unmeasurable.

		brach- ial				
	length	valve length	surface length	mid- width	hinge width	height
USNM 725k						
151611a	18.5	35.0	28.6*	20.6	10.6?	7
151611b	18.0	32.0	22.8+	24.6	10.4?	?
151611c	16.0	31.0	28.0	21.0	8.1	?
151611d	19.5	41.0	29.6	26.0	14.7	8.7
USNH 738a						
151614a	19.7	36.0	31.2*	25.4	13.7	?
151614b	18.4	38.0?	26.6*	21.5	10.8	?
151614c	17.9	38.0	27.0*	20.7	10.4	?

Brachial valve with deep umbonal depression leading into deeply concave median region; sides and anterior sloping steeply. Fold inconspicuous and visible mostly on trail. Ears moderately concave. Costae indistinct on brachial valve and no spines present.

Interior poorly known but one brachial valve exhibits well-formed lophidium and narrowly arched zygidium. Cardinal process with bulbous myophore.

STRATIGRAPHIC OCCURRENCE.—Capitan Formation.

LOCALITIES.—AMNH 475, 837, 847. USNM 725i, 725j, 725k, 725-1, 731j, 732q, 738a, 739, 740, 740-1, 748a, 750a.

DIAGNOSIS.—Fairly strongly costate *Liosotella* with deep sulcus.

TYPES.—Lectotype: USNM 118523a. Paratype: USNM 118523b. Figured hypotypes: USNM 151611b, c, f. Measured hypotypes: USNM 151611a-d, 151614a-c.

COMPARISON.—This species is not easy to compare with others because it has not yet been found silicified. In all of the specimens available the exterior is mostly exfoliated and the spines can be judged only from their bases or holes left in the shell. This species suggests *L. irregularis*, new species, but differs in having more subdued ornament and finer spines on the spine row.

It also suggests *L. spinumbona*, new species, but that species is thick-shelled and robust rather than thin-shelled like *L. popei*, and it also has stouter spines in the curved row and on the trail, as well as less extended ears and a less transverse brachial valve. *Liosotella tetragonalis* is less strongly costate and has stouter spines than *L. popei*.

DISCUSSION.—This species never has been well understood, and it is doubtful that it occurs outside of the Capitan Limestone. The specimens referred to it by Girty seem to us not to belong here, as indicated in the synonymies. Furthermore, we have also placed in *L. popei* the specimen referred by Girty to *Productus occidentalis*. Newberry's species seems to belong to *Rugatia* rather than in the Paucispini-feridae because it is reticulate on the visceral disc.

It is necessary to correct a statement by Shumard (1860:290) asserting that the "ventral valve" (= dorsal or brachial valve of present terminology) has a row of spines on its sides. The brachial valve of this species is quite definitely without spines, as is characteristic of the genus. Girty (1909:258) sug-

gested that crushed pedicle valves had been mistaken by Shumard for the brachial valve.

Although none of our specimens shows the interior in detail, some important features may be seen. Specimen USNM 151611e shows the zygidium to perfection and the bulbous cardinal process is visible in some others. The generic identity of the species seems thus beyond question.

*Liosotella rotunda*, new species

PLATE 154: FIGURES 6, 7; PLATE 192: FIGURES 46–57; PLATE 446: FIGURES 23–33

Small for genus, variable outline, length and width nearly equal; sides flattened and sloping slightly medially; anterior margin moderately rounded; ears small, variable, slightly acute to slightly obtuse. Surface variable, usually fairly costate with rounded costae varying from strongly elevated to slightly elevated, number variable from 9 to 15 with posterolateral extremities indistinctly marked. Spines variable in number, row over ears ranging from 2 to 5, few scattered spines on body and trail.

Pedicle valve strongly convex in lateral profile, maximum convexity slightly posterior to middle; anterior profile narrowly domed and with steep sides. Trail slightly inflated. Beak small, umbo slightly protruding posterior to hinge. Sulcus indistinct, variable from narrow to broad and shallow, occupied by one to three costae. Brachial valve deeply and evenly concave, closely fitting concavity of pedicle valve. Ornament on posterior subdued but stronger along margins; ears deflected and slightly concave.

MEASUREMENTS (in mm).—Thickness of holotype 3.3; of others, unmeasurable.

	length	brach- ial valve length	surface length	hinge width	mid- width	height
USNM 732j						
154122a	15.0	12.8	27.0	16.0	17.2*	9.6
(holotype)						
154122b	14.1	?	25.0	14.7	15.5	8.2
USNM 736x						
155036a	12.0	?	19.0	14.5	15.5?	7.6

Pedicle valve interior with strongly demarcated ears; interior spine bases occurring in row under ear ridges and corresponding to external row over

ears; adductor ridge moderately thickened; inner surface granulose. Brachial valve interior with strong zygidium bearing narrow lophidium medially; cardinal process with narrow myophore; adductor region slightly thickened; endospines small. Brevisseptum low.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 732j, 736x.

DIAGNOSIS.—Deeply concave, costate *Liosotella* having length and mid-width subequal in the adult.

TYPES.—Holotype: USNM 154122a. Figured paratypes: USNM 154122a–c; 153912a, b; 155036b. Measured paratypes: USNM 154122b; 155036a.

COMPARISON.—This species need only to be compared with *L. wordensis* (King) which it resembles and of which it may be the ancestor. The chief distinction is the fact that *L. rotunda* is a narrower shell based on measurements of length and mid-width. An average of the length-width ratio of 23 random specimens is 0.90. Young specimens tend to be somewhat wider but they have not yet fully developed the trail. *Liosotella wordensis* has more distant costae than the Road Canyon species and tends to a larger size when fully grown. The largest specimen of *L. rotunda* is much smaller than the larger specimens of the Word species. The brachial valve interior of *L. wordensis* is completely different from that of *L. rotunda*, as it has a larger and wider cardinal process, stronger endospines, and a more positive development of other features. *Liosotella rotunda* is a relatively rare species.

*Liosotella spinumbona*, new species

PLATE 414: FIGURES 1–38

Fairly large for genus, length and midwidth about equal; hinge equal to or slightly greater than width; sides rounded; anterior margin broadly rounded and indented medially; ears triangular, usually large. Surface strongly costate except for smooth or faintly radiate umbonal region; costae strongest on venter and trail, numbering one to three per 5 mm on trail. Spines fairly numerous: in row of four stout spines on lateral slopes; two to several large spines on trail, usually near midtrail; and indefinite number of small spines on umbo and visceral disc.

Pedicle valve unevenly convex in lateral profile, posterior third flattened, adjacent third (venter)

narrowly convex, and anterior third, or trail, forming long, gently convex slope; anterior profile a narrow, steep sided dome indented medially. Umbo swollen and with moderately steep slopes toward ears. Venter strongly inflated. Sulcus originating between venter and umbo on visceral disc, deeply U-shaped, extending to anterior margin. Flanks bounding sulcus narrowly rounded and steep-sided. Ears rounded, usually bluntly pointed in adults but acutely pointed in young specimens.

Brachial valve deeply concave, most concave in median region; trail long and steep; umbonal region deeply depressed; fold low and inconspicuous, originating near midvalve; ears demarcated by narrow change in slope, moderately concave. Brachial valve poorly costate, costae strong only on trail.

Pedicle valve interior with well-marked ginglymus: ear baffles strong, fluted, not elevated but over-

hanging visceral region and continued medially to delthyrium as ridge. Adductor platform greatly thickened and expanded anteriorly, uniting with median ridge formed by sulcus; diductor scars small, transversely but broadly elliptical; interior surface strongly pustulose. Spine ends commonly elongated.

Brachial valve interior with poorly developed lateral ridges, which, when present, are low and oblique; ear baffles low but strongly striated and usually extended anteriorly as distinct ridge around visceral region. Cardinal process large, median lobe narrow; zygidium small, well developed. Adductor platform small, thickened, and bearing lobate inner adductors; outer adductor scars at sides of platform and lightly impressed. Brevisseptum delicate, free, and protruding at distal end. Endospines large, long, and in one or two rows. Brachial ridges well formed.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 728							
149586a	24.6	?	50.0±	23.0	23.4	16.6	?
149586b	26.8	?	52.0	27.2	26.2	18.0	?
149586c	23.5	15.7	46.0	25.7	24.0	16.6?	8.5?
(holotype)							
149586d	24.3	?	47.0	25.6	24.2	16.0	?
149586e	22.6	16.0	43.0	26.6	24.1	14.0	6.9
149586f	22.6	17.0	44.0	25.4	22.4	15.6	8.7
149586g	22.4	?	46.0	25.2	23.7	15.7	?
149586h	20.7	16.0	41.0	23.3	21.4	14.0?	7.0
149586i	19.0	14.5	32.0	26.6	22.4	12.3	6.5
149586j	18.9	15.0	35.0	24.9	21.4	12.0	5.3
149586k	18.7	14.3	33.0	25.5	20.6	12.0	4.7
149586l	17.6	15.2	28.0	20.5	20.6	10.0	5.4
149586m	16.7	14.2	25.5	20.6	20.0	9.0	2.8
149586n	15.4	13.7	23.0	17.1	19.0	7.7	2.6
149586o	15.0	?	20.0	17.3	17.8	5.6	?

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member).

LOCALITIES.—AMNH 21, 600, 512; USNM 728.

DIAGNOSIS.—Square, costate *Liosotella* having stout halteroid spines, and small spines on the umbo and visceral disc, and poorly costate brachial valve.

TYPES.—Holotype: USNM 149586c. Figured paratypes: USNM 149586e, j, k, p, q, s–w. Measured paratypes: USNM 149586a, b, d–o. Unfigured paratypes: USNM 149586a, b, d, f–i, l–o, r.

COMPARISONS.—This species is very similar in

general form and ornamentation to *L. tetragonalis*, new species, of the Word Formation (lens between Willis Ranch and Appel Ranch members) of the Glass Mountains. Although the length/width ratios of the two species are nearly the same, they nevertheless differ importantly in many details. The Guadalupe species generally attains a larger size than the Glass Mountains form and the ornamentation of its pedicle valve is stronger. The halteroid spines of *L. spinumbona* are much stouter than those of *P. tetragonalis* but the latter lacks the nu-

merous small spines that adorn the visceral disc and umbonal region of the Guadalupe species. None of the Greenland species of *Liosotella* is similar to this one (Dunbar, 1955).

**DISCUSSION.**—This species has strongly developed interior characters. Inside the pedicle valve the extension of the spines from the interior is considerable, between 2 and 3 mm in one specimen. The ear baffle striations are strong and the muscle platform long and large. It is occupied by the median muscle pairs. The lateral dendritic pair is narrow, elongated, and not easy to see.

In the brachial valve a distinct submarginal ridge is developed in many specimens. The strainer spines are large and long. The brevisseptum is unusually developed and greatly elongated, the distal end forming a long free blade. The cardinal process in old specimens may be ponderous, with the median lobe roughened, so that the ensemble suggests the linoproductid cardinal process.

### *Liosotella tetragonalis*, new species

PLATE 413: FIGURES 1–39; PLATE 414: FIGURES 39, 40

Medium size for genus, quadrate outline, length and width nearly equal; hinge wide, equal to or slightly wider than midvalve; ears moderately large, generally triangular, slightly acute. Sides and anterior margin gently rounded; anterior margin

indented. Surface costate, costae few, usually indistinct on visceral disc, strong on venter, variable on trail. Numbering two or three per 5 mm. Halteroid spines few; in row of three or four on lateral slope and hanging over spineless ear; and two or more near middle of trail and generally on each side of sulcus; occasional scattered or random spines on trail.

Pedicle valve unevenly convex in lateral profile, venter narrowly rounded, but visceral disc gently curved and trail much longer than visceral disc and strongly rounded. Anterior profile forming a high, steep-sided dome, indented medially. Beak small, umbonal region narrowly swollen, moderately steep-sided. Venter strongly arched and posterior in position. Trail long and strongly curved, more than twice length of visceral disc in large adult. Sulcus originating about 7 mm anterior to beak, moderately wide and deep, U-shaped, and extending to anterior margin. Flanks bounding sulcus narrowly rounded and with very steep sides.

Brachial valve deeply concave, greatest depth at midvalve, trail and sides nearly vertical; ears concave, well marked by oblique ridge; umbo deeply depressed, fold originating at midvalve, moderately strong.

Pedicle valve interior with ear baffles not elevated but with inside surface striated; ginglymus present; adductor platform long, strongly elevated, and ex-

### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706b							
149591a	22.6	14.7	45.0	24.3	23.3	15.4	7.7
(holotype)							
149591b	21.8	16.0	42.0	24.0	22.5	15.3	7.0
149591c	22.7	14.6	43.0	25.5	21.9	15.0	6.4
149591d	21.0	13.7	43.0	23.5	21.4	13.7	6.0
149591e	19.0	14.4	40.0	24.5	20.1	13.8	5.9
149591f	20.0	14.0	39.0	19.8	18.8	13.6	5.1
149591g	18.8	13.4	38.0	26.0	22.8	12.5	4.6
149588h	18.2	13.3	39.0	23.0	21.9	14.0	5.8
149591i	19.6	14.5	35.0	22.8	19.3	13.0	6.4
149591j	18.0	14.4	35.0	23.2	21.0	11.6	6.0
149591k	17.8	13.3	35.0	23.2	21.2	11.6	5.2
149591l	16.2	13.3	27.0	20.0	17.9	9.3	2.8
149591m	15.0	13.0	26.0	25.0	18.8	9.0	3.5
149591n	14.0	11.9	20.0	18.6	17.1	5.9	2.0
149591o	13.1	?	17.0	13.2	15.2	4.8	?
149591p	10.5	9.0	14.0	8.3	11.7	4.5	1.7

panded anteriorly. Interior extensions of spines well developed in many specimens.

Brachial valve interior with well-developed lateral ridges uniting with slightly elevated ear baffles; submarginal ridge from ear baffles indistinct. Adductor platform thickened and occupied by inner pair of adductors, each divisible into two lobes. Outer adductors indistinct, forming crescent-shaped scar in pit below the adductor platform. Cardinal process variable, rounded; zygidium strongly developed in adult. Brevisseptum free distally; brachial ridges well thickened. Endospines long and thick, in one or two rows.

STRATIGRAPHIC OCCURRENCE.—Word Formation (lens between Willis Ranch and Appel Ranch members and Appel Ranch Member).

LOCALITIES.—Lens: USNM 706b, 732c, 737w. Appel Ranch: USNM 714o.

DIAGNOSIS.—Compact, moderately umbonate *Liosotella* with nearly square outline in the adult.

TYPES.—Holotype: USNM 149591a. Figured paratypes: USNM 149511 b; 149590a, b; 149591b, o-s, u, w. Measured paratypes: USNM 149591 b-p. Unfigured paratypes: USNM 149511a; 149591c-n, t, v.

COMPARISONS.—This species is common in a lens of limestone between the Willis Ranch and Appel Ranch members of the Word Formation. It is most like *L. spinumbona*, new species, in its exterior expression and is almost identical to it in its length-width ratio. It differs in having more subdued ornamentation, a more narrowly rounded venter in lateral profile, more vaulted umbonal region, and less spiny umbonal region than *L. spinumbona*.

DISCUSSION.—This species has very positive interior characters; the inner spines are longer than other species and the diductor scars are more nearly circular and are strongly impressed. The adductor platform is thick and expanded anteriorly, with the median muscles strong but irregularly impressed. The lateral scars are difficult to discern. The callus deposit posterior to the diductors is very thick in many specimens. The ear baffle is strong and usually extends medially to form a ridge nearly reaching the beak. The inside of the ridge is commonly striated.

Although the brachial valve has strongly developed features, it is not provided with a well-defined ridge from the ear baffles around the posterior edge

of the trail. Strainer spines are few but large and prominent. The brevisseptum is usually delicate, but the cardinal process may become large. The size of the cardinal process, as in other species, is not determined by shell size, because some small specimens have larger processes than do the larger ones. In one aberrant specimen the median lobe protrudes toward the pedicle valve in a large lobe as wide as the process.

### *Liosotella texana* (Girty)

PLATE 208: FIGURES 5-8

*Productus texanus* Girty, 1909:259, pl. 21: figs. 25, a-c, 26a-b.

This species is represented by Girty's two type specimens, a fair pedicle valve and a poorly preserved impression of the exterior of the brachial valve. The pedicle valve is strongly auriculate and has small pointed cardinal extremities. The surface is marked by narrow but strong radial costae crowded with low, rounded crests. A strong median sulcus extends from the visceral disc region to the anterior margin. Spines are difficult to discern but a large one, probably the first formed of a row over the ears, is on the slope overhanging the ears. The brachial valve closely follows the pedicle one with costae of equal strength and a fairly strong median fold.

The two species in the Glass Mountains like this one are *Liosotella costata*, new species, and *Paucispinifera costellata*, new species. The former is shorter, wider, and more strongly costate than *L. texana* and the latter is almost identical in shape, but the ornament is fine and delicate, hence its assignment to *Paucispinifera* rather than *Liosotella*.

MEASUREMENTS (in mm).—From locality USGS 2903, specimen USNM 118526a (lectotype): length 19.0, hinge width 22.6, surface length 36.0.

STRATIGRAPHIC OCCURRENCE.—Delaware Mountain Formation (about 700 feet above the basal black limestone in the Delaware Mountain Sandstone of the Cherry Canyon Formation).

LOCALITY.—USGS 2903.

DIAGNOSIS.—Quadrant *Liosotella* with regular, moderately strong and crowded costae.

TYPES.—Lectotype (chosen here): USNM 118526a. Figured paratype: USNM 118526b.



*Liosotella wordensis* (R. E. King)

PLATE 411: FIGURES 1-71; PLATE 412: FIGURES 19-42

*Productus* sp. A Girty, 1909:260, pl. 21: figs. 24a-c.*Marginifera?* *wordensis* R. E. King, 1931:90, pl. 23: figs. 8-11.*M. texana* R. E. King (not Girty), 1931:89, pl. 23: fig. 5.

Small, transversely rectangular in outline; hinge equal or slightly wider than midwidth. Ears naked, angular and prominent in young, rounded and less conspicuous in adults. Sides slightly rounded; anterior margin gently rounded to truncate. Spines all of halteroid type, numerous; consisting of row of four to six at base of lateral slope overhanging ears and attaining length of 0.5 inch or slightly more, scattered small spines on umbonal and visceral disc regions, and scattered larger spines on trail, these without definite pattern. Umbonal and visceral regions without radial ornament; venter with somewhat subdued costation, often irregular, but trail marked by strong, rounded costae ranging in number from few to 16.

Pedicle valve narrowly rounded in lateral profile, with venter most rounded, visceral disc and umbonal regions flattened, and trail gently rounded. Anterior profile a steep-sided dome flattened somewhat at top. Beak small; umbonal region nearly smooth and gently convex; venter narrowly rounded, with incipient costae. Sulcus originating on venter, shallow and inconspicuous, barely indenting anterior margin, usually occupied by two costae but in some specimens by one or none. Flanks bounding sulcus well rounded and with precipitous sides.

Brachial valve deeply concave, maximum concavity in midvalve; umbonal and visceral disc regions nearly smooth; fold originating near midvalve, indistinct, usually consisting of one or two slightly elevated costae; trail prominently costate but costae less rounded and less elevated than on pedicle valve; sides steep; ears concave, demarcated by narrow oblique fold.

Pedicle valve interior with moderately developed ear baffles; internal spines commonly prominent, especially extensions of row on lateral slopes which usually forms corresponding row just ventral to ear baffle. Adductor platform seldom thickened, even in old specimens. Surface anterior to muscle field usually papillose.

Brachial valve interior with all structures mod-

erately pronounced in adults; ear baffles low and indistinct, forming anterolateral and anterior marginal ridges only rarely; cardinal process small, variable, well lobed, with narrowly arched zygidium and prominent, narrow lophidium. Adductor platform small, seldom thickened even in old individuals; median scars small, but larger than indistinct lateral ones. Brevisseptum a thin blade, distally free. Brachial ridges usually not visible or indistinct, narrowly looped and thick in old shells. Strainer spines variable, usually small and delicate and usually forming band at zone of geniculation.

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation, Cherry Canyon Formation (Getaway Member), Road Canyon Formation, Word Formation (China Tank, Willis Ranch, Appel Ranch members, and lenses between the last two).

LOCALITIES.—Cathedral Mountain: USNM 714v. Getaway: AMNH 21, 496, 512, 519, 600; Moore 31; USNM 728, 730, 732. Road Canyon: USNM 700v, 707e, 716xa, 721j. Word: USNM 731m, 731u, 732s, 737b, 741p. China Tank: USNM 703e, 706c, 706z, 713, 726r, 733q. Willis Ranch: AMNH 505, 506. USNM 706, 706e, 723t, 723w, 724u, 735c. Lens: USNM 706b, 732c, 737w, 742b. Appel Ranch: USNM 704, 714o, 719z, 726t.

DIAGNOSIS.—Small, strongly costate *Liosotella* with numerous spines on visceral disc and trail.

TYPES.—Lectotype: T9998a; paratypes: T9991a, b; T9998b. Figured hypotypes: USNM 149593e; 149595d, h, i, j, s, v, w; 149613a, b; 153933a, b; 153934a-i; 153935a-e; 153936a, d; 153937a-c; 153938a-f. Measured hypotypes: USNM 149592a-j, 149593a-o, 149594a-g, 149595a-u.

COMPARISONS.—This is the smallest of the Glass Mountains species of *Liosotella* and is thus unlikely to be readily confused with any other species. It differs from *L. parva*, new species, by its much stronger costae and its relatively poor development of the sulcus. It is generally smaller and has a different shape than *L. grandicosta* Dunbar, although aberrant large forms are similar.

*Liosotella wordensis* strongly resembles *Elliotella* Stehli and the species of the two genera are quite similar in external appearance. *Elliotella*, however, is not provided with a zygidium and the spine arrangement is different, a row of spines embellishing the posterior margin.

DISCUSSION.—The exterior ornament of this spe-

## MEASUREMENTS (in mm).—

	<i>length</i>	<i>brachial valve length</i>	<i>surface length</i>	<i>hinge width</i>	<i>midwidth</i>	<i>height</i>	<i>thickness</i>
USNM 706e							
149595a	18.7	?	33.0	18.4	17.1	11.8	?
149595b	15.5	?	28.0	19.0	17.2	9.6	?
149595c	15.2	?	26.5	17.6	16.9	9.2	?
149595d	16.5	?	29.5	20.8	20.0	10.2	?
149595e	13.8	11.2	24.5	17.0	16.8	9.2	4.0
149595f	13.4	11.3	24.0	15.9	15.7	8.9	3.8
149595g	12.2	10.0	22.0	17.0	16.0	7.4	2.8
149595h	11.9	10.6	18.5	14.4	14.6	5.2	1.8
149595i	9.4	8.4	13.0	12.0	11.4	4.1	1.0
149595j	7.9	7.0	10.0	6.8	7.6	2.8	1.0
149595k	14.6	?	27.0	19.2	16.7	9.2	?
149595l	13.4	10.0	25.0	16.4	13.9	8.5	3.6
149595m	11.9	10.2	22.0	14.8	13.1	7.6	2.7
149595n	13.3	?	25.0	18.0	16.8	8.1	?
149595o	14.0	?	25.0	17.9	16.7	8.1	?
149595p	9.8	8.5	15.0	11.4?	12.1	3.8	1.7
149595q	14.0	?	28.0	17.6	17.0	9.6	?
149595r	12.5	?	22.0	15.4	14.5	7.6	?
149595s	12.8	10.0	25.0	17.0	13.7	8.5	3.4
149595t	10.6	?	17.0	13.8	12.7	5.0	?
149595u	10.2	?	16.0	10.7	11.7	4.7	?
USNM 706							
149592a	13.4	?	26.0	18.3	16.4	9.2	?
149592b	14.0	?	24.5	18.9	17.8	8.6	?
149592c	13.1	?	23.5	16.7	15.4	7.9	?
149592d	14.0	?	25.5	17.0	15.3	9.0	?
149592e	12.2	?	21.0	16.7	15.5	7.2	?
149592f	11.6	9.4	22.0	14.9	13.4	8.0	4.1
149592g	11.5	?	21.0	15.0	15.0	7.4	?
149592h	11.0	?	19.0	14.8	14.8	6.2	?
149592i	14.2	?	26.0	15.7?	15.8	8.2	?
149592j	14.3	?	25.0	21.0	18.2	8.3	?
USNM 706b							
149593a	16.3	?	32.0	19.3	19.0	10.4	?
149593b	13.9	9.8	28.5	18.3	16.5	9.7	4.3
149593c	12.2	10.2	23.5	17.0	15.7	9.0	3.9
149593d	13.0	10.0	25.0	16.4	14.6	8.4	4.0
149593e	13.9	10.3	28.0	18.5	16.0	8.9	3.2
149593f	13.8	10.7	27.0	16.6	15.9	9.3	4.8
149593g	12.6	10.8	23.0?	14.1	15.0	7.2	2.6
149593h	12.8	9.7	24.0	14.1	14.1	8.1?	4.2?
149593i	11.8	9.5	22.0	14.9	14.0	7.5	3.0
149593j	12.4	10.5	22.0	18.6?	15.9	7.6	2.9
149593k	10.3	9.4	13.0	14.4	12.3	6.1	2.0
149593l	9.9	8.1	17.5	14.6	12.3	5.9	?
149593m	9.7	8.5	15.0	11.0	12.0	5.0	2.0
149593n	9.2	8.2	13.0	13.2	11.5	3.7	1.2
149593o	7.4	6.5	9.0	6.5?	8.5	2.2	1.0
USNM 706c							
149594a	12.8	10.2	22.0	12.8?	16.6	7.5	3.3
149594b	13.6	11.2	23.0	14.1	15.9	7.9	3.5
149594c	12.8	9.9	24.0	14.8	14.9	8.0	3.9

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
149594d	12.5	10.4	24.0	16.6	14.9	7.6	3.0
149594e	11.5	9.8	21.5	13.4	13.6	7.5	3.0
149594f	13.1	10.7	24.0	19.5	16.1	9.0	3.3
149594g	9.9	9.1	10.0	13.2	13.1	4.0	1.3

cies is variable, especially in the younger specimens before the costation has become strong. In these the costae are generally smaller and narrower and have a tendency to bifurcate. After the geniculation of the shell has proceeded and adult form reached, the ribs become strong and fixed. The features around the sulcus are also variable. In some specimens the sulcus may extend from venter to anterior margin without development of costae within it. It is more usual, however, for the sulcus to contain one or two costae.

The pedicle valve interior of this species has no especially noteworthy features except the development of the inner spines, i.e., extensions into the interior of spines from the outside. The row of spines at the base of the lateral slopes also makes a row of tubes on the inside located just under or ventrad of the ear baffles. These tubes project into the shell in an anterodorsal direction. Generally they are mere nubs but in some specimens attain a length of 1 mm or more.

Brachial valves are extremely variable in shape and concavity. Any variation subjects the interior details to change. The species has no unusual interior details, each of the structures being lightly developed in the young and somewhat stronger in adults. Only old or obese specimens have unusual thickening of the structures. As in most productids the largest specimen does not necessarily attain the maximum development of the interior. It is a common occurrence in this species for the larger shells to appear to be younger and have a modest development of the interior details and some smaller ones may indicate old age by structures that are greatly thickened. As noted below, the interior details of specimens from different localities differ in development.

**GROWTH.**—The development of this species is much like that of other members of the Paucispini-feridae. The smallest specimens are not uniform

in shape but may be circular or elongate oval or slightly wider than long. They all have a deformed umbo, usually with hairlike irregular spines surrounding the pressure scar where the shell adhered to a hard surface. These spines, because some of them are abruptly bent at a high angle at their distal ends, may have been actually rhizoid spines helping to cement the spat to its abode. Some young of *Liosotella* are provided with one or more rings at the umbo in addition to the spines mentioned. Perhaps the most conspicuous spines are those that occupy the base of the lateral slope. These are usually the largest on the shell and attain a length of 11 mm on a specimen 4.5 mm long. Two spines 5 mm long formed on each side of a specimen of 10 mm length. Specimens shorter than 5 mm are generally smooth but beginning at about 7 mm costation is variably developed and the costae widely spaced. Geniculation and the development of the sulcus also start at about this stage.

Occasional specimens of large size have characters of this species but they also are sufficiently different to raise a doubt as to whether they are aberrant or belong to a different but rare form. One such pedicle valve from USNM 706b is 18 mm long and 20 mm wide at the hinge. Midwidth is slightly narrower than that at the hinge. The deep sulcus of this specimen is a significant difference from the general ensemble. But sulci are among the most variable features of a productid; consequently these few large forms have been placed tentatively with *L. wordensis*.

**THE TYPE-SPECIMEN.**—King (1931, pl. 23) figured four specimens to illustrate his species, two from University of Texas locality Tx and two from T240. The former two are silicified specimens from Hess Canyon, probably similar to specimens from USNM 706 and 706e, both from the Word Formation (Willis Ranch Member). The second pair of specimens are also from the middle Word but come

from the mountain, 1.5 miles N 55° W of the Hess Ranch House, that is approximately on hill 5801 just north of Leonard Mountain. The middle Word or Willis Ranch Member is well exposed on this hill. The two silicified specimens (T9991), which are pedicle valves, are badly damaged. The other two specimens (T9988) are in limestone matrix but represent impressions of the exterior of brachial valves, not pedicle valves as recorded on the legend to plate 23 (King, 1931:196). None of these specimens is adequate for a lectotype but they constitute the only available choice. We have, therefore, selected the larger of the two brachial valves and this is now numbered T9998a.

**STRATIGRAPHIC VARIATION.**—The specimens from the three stratigraphic levels and four localities all have features that set them apart when seen in the aggregate but hardly constitute sufficient evidence for specific or even subspecific names. Some of the seeming similarities are caused by preservation, which yields specimens prevailing of different color that tends to set each locality apart, whereas analysis of shell features seems to weld them into a single species.

**USNM 706:** These specimens are lighter colored than all the others, tending to a dirty cream-color. Although large adults conform well with the average of the species, many specimens have immature ornamentation characters, ribs irregular and with wide interspaces, and generally with a somewhat wider hinge than those from other localities.

**USNM 706b:** These specimens, as a whole, seem to be somewhat smaller than those from USNM 706 and are light colored but with considerable rusty brownish red stain. The ornamentation generally is more mature and the hinge tends to be slightly narrower.

**USNM 706c:** In color, specimens from this locality are like those of the preceding place. The specimens are generally small and are shaped more like those of USNM 706e, but with some immature ornament characters like those of USNM 706.

**USNM 706e:** This is the most prolific locality for this species and the one that seems to represent the species best. Its hinge character is intermediate between the wide-hinged forms of USNM 706 and the narrower ones of USNM 706b. Its ornament characters are rather more like those of USNM 706 than of the other two localities, having a fair scattering of specimens with immature characters.

## Genus *Paucispinifera* Muir-Wood and Cooper, 1960

*Paucispinifera* Muir-Wood and Cooper, 1960:319.—Williams et al., 1965:H505.

Medium to large, transversely subrectangular to subelliptical outline; deeply concavo-convex; hinge forming widest part; ears prominent; sides sloping medially; anterior margin broadly rounded, usually sulcate. Surface poorly costate, radial elements most prominent on visceral disc and venter, becoming obscure on trail. Anterior commissure with narrow, low fold. Spines confined to pedicle valve, few; in row along posterior margin; few spines over ears and few large spines on trail; small scattered spines on visceral disc. Brachial valve without spines.

Pedicle valve with minute beak; ginglymus short and curved, when present; ear baffles prominent, striated; adductor platform thick, triangular.

Brachial valve with prominent curved lateral ridges joining elevated and striated ear baffles to form submarginal ridge terminating near midvalve; cardinal process sessile, deeply indented medially, median lobe narrow and corrugated; lateral lobes small, deeply indented and corrugated; zygidium arched and prominent. Adductor field subrhomboidal in outline, consisting of median elevated platform and small, outer dendritic scar. Inner platform made up of two tear-shaped scars, inner pair being longer. Brevisseptum prominent, strongly elevated, and bladelike at distal extremity. Brachial ridges prominent, inner loops elevated. Endospines large anteriorly and forming submarginal ridge continuous with ear baffle. Trail covered by small endospines.

**TYPE-SPECIES.**—*Paucispinifera auriculata* Muir-Wood and Cooper (1960: 320, pl. 122: figs. 1–16).

**DIAGNOSIS.**—Usually transversely rectangular, zygidium-bearing shells with poorly developed radial ornamentation.

**COMPARISON.**—Very few genera are provided with a prominent zygidium such as that of *Paucispinifera*. *Liosotella* Cooper is the best known one and is closest of all genera to *Paucispinifera*. They differ, however, in the general transverse shells of *Paucispinifera* which have ornament chiefly in the visceral disc region, the trail being very indistinctly costate whereas *Liosotella* is usually strongly costate on both trail and visceral disc. A variety of

small productids, especially some of the Marginiferinae, suggest *Paucispinifera* but they do not have a zygidium. For further discussion see *Liosotella*.

DISCUSSION.—The exterior details of this genus are important to its classification. The external ribbing, which in some is of the order of costellae but in others definitely costae, is variable in its arrangement on the shell. In most examples the radial ornament is confined to the visceral disc and the venter. The trail is usually smooth or nearly so. Some specimens have radial ornament on the trail, but these are rather an exception. Radial ornament is clearly developed on the visceral disc region of the brachial valve; it usually runs onto the trail, and is well developed along the anterior margin. The ears on some are smooth but in other species they are costate, either wholly or on the anterior slopes.

The spines, confined to the pedicle valve, although irregular in development, have a definite pattern. The posterior margin, including that of the ears, is adorned by a row of spines. The outermost spine near the end of the ear is the largest in each row. A row of spines runs obliquely near the base of the umbonal and lateral slopes from near the beak to about midvalve on the lateral slope. Usually all but the last spine in this series is small and insignificant, or defined only as a node. The last spine is one of the largest present on the valve. It forms the outside of a row of four or five large spines located on the trail just anterior to the venter. All these halteroid spines helped to keep the shell balanced on the visceral disc. In addition to these large spines a few smaller ones are scattered randomly on the venter and visceral disc. The spine plan, involving generally large spines, is similar to that seen on some of the Marginiferidae, such as *Kozlowskia* Fredericks and *Eomarginifera* Muir-Wood.

The pedicle valve interior is patterned after that of the Marginiferidae and offers no new features. It should be noted that the ear baffles are especially prominent and are deeply striated on the inner surface. They make a distinct platform for the ear.

Another feature of considerable importance is the manner in which the large halteroid spines open into the inside of the valve and how some of them are closed off with growth. The spines on the lateral slopes of the exterior are usually extended internally as short tubes located just ventrad to the

ear baffle. These tubes may attain a length of 1 or 2 mm or, in exceptional cases, more. In the younger shells these spines open directly to the interior without a tube. This is especially true of the two, occasionally three, large spines on the trail on each side of the sulcus. These spines are usually represented by round holes rather than tubes in the young but tubes are not developed in the older shells.

With growth and age the openings of all these spines are gradually sealed. Specimens showing elongated plugs under the baffles indicate that the tubes are ultimately sealed off. The manner of sealing off both tubes and holes seems about the same. Shell substance is deposited unevenly on the side of the tube orifice or inner aperture of the spine, narrowing the orifice longitudinally or laterally. The spines on the interior, and the tube apertures, are represented first by elliptical holes and then by mere slits before they are finally sealed completely.

Some brachial valves in the collection exhibit all interior details to perfection. The cardinal process is variable as in all productids, but conforms well to the family characters that include the usual zygidium. The cardinal process shares features with the Marginiferidae, and some with the Linoproductidae. No shaft has been observed in any specimen. The median lobe is narrow and directed dorsally but it is never drawn as far in this direction as that of the Marginiferidae. Furthermore, the posterior face of this lobe, which is usually narrow, is strongly striated in a transverse direction. The lateral lobes are essentially small cups on each side of the median lobe, well striated transversely on their floors. The lateral walls are shallow and the cups are deeply excavated.

The zygidium, one of the characteristic features of this family, forms a protective arch over the dorsal side of the cardinal process. Laterally from the zygidium two ridges extend to the inside of the posterior margin and unite with the lateral ridges.

The lateral ridges are fairly strong and moderately elevated, extending slightly anterolaterally or obliquely to the posterior margin to join the strongly elevated ear baffle. The latter structure forms a strong and precipitous ridge inside the ear and on the outside of the lateral disc. In effect the zygidium, lateral ridges, and ear baffles form a single curved ridge defining the visceral area laterally



and posteriorly. Completing this bounding ridge is an anterior row of stout and long endospines, corresponding to the thickened margin of the Marginiferidae (Grant, 1968).

The adductor platform is worthy of note because of the distinctness of its parts and the light that it may ultimately shed on the musculature of these animals. Six distinct scars are visible in most specimens, four separated by the brevisseptum into two groups of two each, and an outer two having a completely different form. The two inner pairs form an elevated platform of two triangles with their bases facing the brevisseptum and the apices facing laterally. Each triangle is marked by an elongated inner scar with its anterior end looped posterolaterally. The outer scar is in contact with the inner one and is shorter and teardrop-shaped, terminating with its anterior end forming the apex of the triangle. The outer scars are dendritic and lie posterodorsal to the elevated median triangular patches.

Younger specimens do not show these details as clearly as the old and thickened ones. The same elements are present, but the median pairs are not thickened and elevated, and are not always clearly distinguished into their left and right elements. The outer scars are usually not strongly impressed and are seldom dendritic in the young.

The brachial ridges are well developed in this genus but show no unusual features except the considerable elevation of the lateral and inner loops in old specimens.

**GROWTH.**—The smallest pedicle valve of *P. auriculata* Muir-Wood and Cooper is about 4 mm wide and about the same length. It is nearly smooth and gently convex. Slender spines appear along the posterior margin, one on each side of the umbonal slope. Evidence of the presence of an attachment ring may be seen on this specimen. A specimen about 5.5 mm wide and another 13 mm wide preserve a large attachment ring. Probably the young were attached by this means and the ring was functional until a length of at least 13 mm was attained. With increasing growth spines continue to appear in a row at the base of the lateral slope. The maximum number observed is three in the young of *P. auriculata* but five may appear in the adult. Although these spines may be extremely long in proportion to the small size of the shell, the innermost two seldom survived the

rigors of life and are usually preserved in adults only as nodes or short stubs. Radial costation is vague in the smallest specimens but becomes distinct after a length of about 5 mm. Sulcation appears after about 5 mm and geniculation takes place at from 12 to 15 mm.

The brevisseptum of the young brachial valve is scarcely visible and the cardinal process is different in shape from that of the adult. In the very young, and in specimens up to at least 10 mm in length, the cardinal process is sessile but is very narrowly compressed and very long. The umbonal region of the young brachial valve is concave, this concavity producing a sort of platform on which the compressed cardinal process is located. Seen from the ventral side the narrow process is deeply indented and two elongated projections extend anteroventrally from its distal end; these may coalesce to form a sort of tumor. The lateral lobes are much reduced, very short, and indented by deep slits on each side of the median lobe. The posterior face of many juveniles shows an elongated median lobe and narrow median lobes passing into the tissue at the posterior margin. At this stage no zygidium is present, but the cardinal process appears to be partly buried in shell tissue.

The zygidium appears at about the 12 to 15 mm stage, or at approximately the length at which sharp geniculation of the trail takes place. The thinner, and presumably younger valves of 12 to 15 mm length have no zygidium, but a wash of shell tissue over the proximal end of the cardinal process is commonly present. As thickening of the interior takes place, the zygidium is formed. Along with the formation of the zygidium comes thickening of the three lobes of the cardinal process and gradual obsolescence of the anteroventral lobes.

Specimens of the same size may have retarded or advanced cardinal processes. Thus a shell about 13 to 14 mm long may have a narrow, juvenile cardinal process but others of the same size may have an advanced process with well-defined lobes and zygidium.

The lateral ridges begin to thicken with the formation of the zygidium. The ear baffles are defined at about the size where geniculation is attained. Brachial ridges are not clearly developed until after geniculation and full adult characters have been established.

*Paucispinifera auriculata* Muir-Wood and Cooper

PLATE 420: FIGURES 1-34; PLATE 421: FIGURES 1-27; PLATE 422: FIGURES 1-20; PLATE 475: FIGURES 14, 15

*Marginifera opima* R. E. King (not Girty), 1931:87, pl. 22: figs. 20, 22, 23 [only].  
*Paucispinifera auriculata* Muir-Wood and Cooper, 1960:320, plate 122: figs. 1-9, 11-16 [not fig. 10].

Large, transversely rectangular in outline; hinge forming widest part; ears large and protruding; sides oblique, gently rounded; anterior margin broadly rounded and usually sulcate; surface costellate to costate, ribs variable, numbering 3 to 5 per 5 mm on venter; umbonal region of both valves usually smooth, visceral disc and venter with costae or costellae, faint to strong, but becoming obscure on anterior part of trail. Spines variable; two or three on each side of beak along posterior margin, last ones of row on ear usually large and long; row of five spines at base of umbonal slope, first three of row generally very small or as nodes but last one usually stout and long; usually one on each side of sulcus on anterior side of venter, but frequently a third spine appearing in sulcus; occasional small to large spines scattered on venter or trail.

Pedicle valve narrowly convex at venter, visceral disc flatly convex and trail moderately convex; anterior profile forming broad dome with steep slopes descending to ears. Beak small, umbonal region

gently swollen; visceral disc moderately swollen; venter narrowly rounded; trail swollen and with steep slope. Sulcus variable, broadly to narrowly U-shaped, shallow to deep and originating about 10 mm anterior to beak. Flanks bounding sulcus well rounded. Lateral slopes steep. Ears extended, well rounded, and costate on anterior slope.

Brachial valve closely fitting interior of pedicle valve; umbonal region shallowly depressed; greatest depth corresponding to venter of pedicle valve; ears concave and deflected abruptly from concave portion. Trail forming high rim around anterior and sides; fold low, subcarinate, originating just anterior to umbonal depression.

Pedicle valve interior with moderately thickened adductor platform widening anteriorly; adductor scars small, separated by low myophragm. Ear baffles prominent; ears concave, forming shallow triangular cavity with elevated rim on posterior and anterolateral sides. Elevated ridge corresponding to external surface and region anterior to diductors marked by mat of fine endospines. Ginglymus short, narrow. Thickened area between beak and ears marked by shallow pits.

Brachial valve interior with low lateral ridges extending directly along posterior margin to join ear baffles, these strongly elevated, forming low wall setting off ears. Baffles uniting with anterior thickening composed of stout and crowded endospines

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706e							
124054a	23.0	17.7	44.0	34.7	31.0	16.0	7.3
124054b	18.8	16.6	35.0	33.0	27.4	15.8	6.7
124054g	19.0	13.0	40.0	39.0	31.3	15.0	?
(holotype)							
124054j	25.4	20.0	49.0	43.0	35.2	18.0	?
149548a	24.1	18.0	50.0	39.3	32.8	18.0	8.7
149548b	24.3	17.4	52.0	43.0	31.4	18.0	9.1
149548c	22.4	20.0	46.0	37.0	29.4	16.3	7.6
149548d	20.7	17.2	25.0	37.9	28.5	12.6	5.4
149548e	18.5	14.7	34.0	33.0	25.4	12.0	5.7
149548f	17.9	15.6	25.0	29.3	25.6	14.3	3.8
149548g	15.2	13.6	22.0	24.6	22.7	13.3	3.1
149548h	13.0	11.5?	15.0	18.8	18.8	3.6	?
149548i	12.0	?	13.0	15.3	17.1	3.3	?
149548j	11.0	?	12.0	13.4	14.4	3.4	?
149548k	8.7	?	11.0	11.1	11.1	2.7	?
149548l	6.7	?	7.5	6.4	7.1	1.7	?
149548m	26.5	18.9	47.0	34.5	35.2	18.3	7.7

and lateral ridges, thus forming wall around visceral region. Cardinal process low, with elongated attenuated median lobe; lateral lobes small. Zygidium well developed. Adductor field of adults thickened; inner adductors elevated; outside, or lateral, adductors small and dendritic. Brevisseptum stout and strongly elevated anteriorly. Brachial ridges defined by thickened loop with elevated margins.

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank, Willis Ranch, and Appel Ranch members, and lens between the last two).

LOCALITIES.—Word: USNM 737b. China Tank: USNM 706c, 706z, 726s. Willis Ranch: AMNH 505; USNM 706, 706e, 724u, 735c. Appel Ranch: USNM 704, 706d, 714o, 715i, 719z, 722t, 726t. Lens: USNM 706b.

DIAGNOSIS.—Transverse *Paucispinifera* having spines on the posterior margin.

TYPES.—Holotype: USNM 124054g. Figured paratypes: USNM 124054a–e, f, h, j; 124055a. Figured hypotypes: USNM 149542a, b; 149545a–f; 149548a, d, g; 153588a–i; 153924; 153989a–f; 153990 153991a–c. Measured paratypes: USNM 124054a, b, j. Measured hypotypes: USNM 149548a–m. Unfigured hypotypes: USNM 149548b, c, e, f.

COMPARISON.—This species, which is abundant in the Word Formation (Willis Ranch Member), is especially characterized by its transverse form and the presence of abundant spines, in addition to the usual complement that characterizes the genus. The predominance of width over length is clear in specimens having a length of about 9 mm as shown by specimens USNM 149548k in the above list of measurements. The young of *P. quadrata*, new species, on the other hand, are distinctly nearly equidimensional below 16 mm.

Perhaps the most conspicuous feature distinguishing the two species is the robust character of *P. quadrata*, with its thick shell and stout form. This species is generally less spinose than *P. auriculata*. In addition to the row of spines on its posterior margin, *P. auriculata* has remnants of the spine row at the base of the lateral slope and usually has scattered spines on the trail and visceral disc. It also commonly has one or more large spines on the trail. *Paucispinifera quadrata* in the adult form seldom shows any trace of the spine at the base of the lateral slopes and seldom has additional large spines on the trail. A few scattered spines on the

visceral disc may be preserved, but they are rare.

*Paucispinifera quadrata* attains a larger size than *P. auriculata* and the sulcus is usually deeper and more strongly developed, with a consequent stronger fold. In both species the ribbing is irregular and tends to die out on the umbonal region and on the trail. That of *P. quadrata*, however, seems to be stronger, especially in the development of the strong rib anterior to each of the major halteroid spines. A strong costa is developed anterior to the large lateral spine of *P. quadrata* in many specimens, and in some is prominent. A similar rib appears in *P. auriculata* but is seldom prominent.

Both species have some details of the interior that differ, but these are not always constant. In the pedicle valve of *P. auriculata* the adductor platform is long and slender and generally only moderately expanded at the front, whereas that of *P. quadrata* is thick and wide at the anterior end. The interior of the brachial valve of *P. auriculata* is generally less strongly thickened and the structures more subdued than those of *P. quadrata*. The cardinal process and zygidium of *P. auriculata* are generally smaller and more delicate than in *P. quadrata* but these are variable features in both species, so some specimens, will be contradictory. The trail of the brachial valve of *P. quadrata* is more deeply indented by the sulcus (seen from the interior) and ear baffles of both valves of *P. quadrata* are thicker and more elevated than in *P. auriculata*.

DISCUSSION.—It is almost impossible to define a definite pattern of spine arrangement for *P. auriculata*. No two specimens appear to be alike, but the four major spines, one over each ear and one on each side of the sulcus on the trail, appear to be standard on all specimens. In addition, most specimens have a large spine on the ear, but the other spines along the posterior margin, which may be prominent in the young, are aborted or broken off in the adult. In this species, more than in *P. quadrata*, supplemental halteroid spines appear on the trail at about the same level as the standard two. These seem to serve the same purpose as the standard spines, but frequently large spines appear elsewhere on the trail, in or out of the sulcus. Small spines may occur anywhere else on the specimen.

In the young the spines of the posterior margin are prominent and may be distinguished from those of the young *Yakovlevia* Fredericks by the high

angle at which they are given off. In some specimens one or more of this row may survive, but usually it is only the last-formed one, which occupies the ear, that exists into adult life.

A similar story may be told of the spines forming a curved row at the base of the lateral slope. In the young these are prominent and frequently of considerable length, but in the adult usually only the last one, the fifth, survives. However, some specimens preserve fairly large third or fourth spines in the row. More commonly, however, these have completely disappeared or are represented by nodes.

The longest spine preserved on any specimen of this species measured 51 mm (2 inches) in length. The species is commonly found in heaps of dead shells and it is thus remarkable that the spines are as well preserved as they are. The two-inch spine is one of the lateral spines but long spines appear on the trail as well. None of these had this length but some were measured at 35 mm (1.5 inches).

**GROWTH.**—Because of the smooth beak and umbonal region of this species it is difficult to be sure of the identity of the smallest specimens. Several other genera at USNM 706e have young that are all quite similar. As would be expected, the young are as variable as the adults; some have attachment rings but others are not so provided.

The smallest specimen (USNM 149545a) of which we feel confident of the identity is 4 mm wide at midvalve and 3 mm long. It has a spine on each side of the beak just anterior to the posterior margin and a larger one (about 2 mm long) at the base of the indistinct lateral slope, near the lateral margin. These two sets of spines are the initial pairs in the row at the base of the lateral slopes, as seen in larger specimens. One spine of the series on the posterior margin is present on the left side but it is not paired. Other small specimens presumed to be the same species have variable spine arrangement. The row of spines along the base of the lateral slopes is constant to all. Some small specimens show stubs or bases of small spines on the umbonal region around the beak that suggest attachment spines. Some of these are bent at a large angle suggesting that they had been attached to another surface.

A specimen (USNM 149545b) 5.5 mm wide and 4 mm long is provided with a broad ring that does not represent the earliest formed spines but is clearly of the second set. The beak of this specimen has a minute but clear scar of attachment. The

spines forming the ring are the initial pair of the spine row along the base of the lateral slopes. The ring may be preserved in specimens up to 10 mm in length.

Between 5 and 10 mm the young pedicle valve USNM 149545c has a row of three spines at the base of the lateral slopes, the ears rounded, the hinge less wide than midvalve, maximum convexity in the midregion, clear development of costellae, and the beginning of the sulcus at about 6 mm from the beak.

At a length of 15 mm the young *P. auriculata* has attained a width of about 21 mm, the spine row has increased to four and the sulcus is strongly developed. Between 15 and 20 mm most of the adult characters are established: the full complement of spines in the row at the base of the lateral slopes, strong costation, and the beginning of geniculation or the formation of the venter. Some specimens between 18 and 20 mm long show the early stages of the development of the two large halteroid spines on the trail. At a full 20 mm of length in many specimens the trail is well developed and the large halteroid spines are established.

#### *Paucispinifera comancheana* (Girty)

*Productus guadalupensis comancheanus* Girty, 1909:261, pl. 31: figs. 5–5b.

*Productus comancheanus* Girty.—King, 1931:67, pl. 11: fig. 1.

This is another of Girty's species that is represented by such insufficient and poorly preserved material that we are unable to establish its true characters. The type specimen is a partial pedicle valve lacking most of its left side. It is strongly alate and has a much extended ear on the opposite side. This auriculation is stronger than usual in *P. auriculata* Muir-Wood and Cooper, but the specimen is more transverse and with stronger ribbing than usual in that species. It suggests *P. transversa*, new species, in its extended auricle and transverse form but it is not ornamented as strongly as that species.

Girty's type specimen comes from the Glass Mountains, from Comanche Canyon, a locality not yet certainly established. It is thus exasperating to be unable to place the species in its proper formation and to identify our abundant specimens with it. R. E. King (1931:67) mentions having but a single specimen of this species in his collection. It is evidently an aberration or a very rare species. In



view of our uncertainty we think it best to recognize Girty's species as valid but not as yet rediscovered. The preservation of the type suggests its source as from one of the Word limestone members, probably the China Tank or lower Willis Ranch Member, in the neighborhood of Split Tank on the Appel Ranch.

Types.—Holotype: USNM 118530.

*Paucispinifera costellata*, new species

PLATE 426: FIGURES 27–31

Medium size for genus, transversely subrectangular outline, hinge forming widest part; ears large, triangular. Sides gently rounded, sloping medially; anterior margin broadly rounded, indented at middle. Surface irregularly costellate, costellae numbering 5 to 7 per 5 mm on trail just anterior to venter; region posterior to venter smooth or nearly so. Halteroid spine pattern as in genus but spines few in number; one on posterior margin of ear, three in row at base of lateral slope, and two on each side of sulcus midway down trail from venter; spines rare elsewhere on trail or visceral disc.

Pedicle valve unevenly convex in lateral profile, posterior half flattened but trail moderately convex; anterior profile broad dome, indented deeply at middle; sides steep. Beak small; umbonal region gently swollen, with short, moderately steep umbonal slopes to posterior margin. Sulcus deep, narrowly to broadly U-shaped, originating at posterior margin of venter; flanks bounding sulcus rounded.

Brachial valve with deep umbonal depression; valve moderately deep, deepest in midregion; ears well demarcated; trail short, steep. Fold originating near midvalve, low and inconspicuous.

Pedicle valve interior with ear baffle not elevated, but muscle field having elevated rim around diductor scars. Brachial valve interior not known.

MEASUREMENTS.—(in mm).—Thickness of holotype 4.7; of others, unmeasurable.

	length	surface length	hinge width	mid-width	height	thickness
USNM 703						
149564	16.1	14.3	28.0	27.0	23.3	10.3
(holotype)						
USNM 707e						
149565a	16.0	13.7	27.0	24.0	22.7	9.7
149565b	16.9	15.5	29.0	27.2	23.6	10.2

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation, San Andres Formation.

LOCALITIES.—Road Canyon: USNM 703, 707e, 720d, 721y. San Andres: AMNH B-188-8.

DIAGNOSIS.—Costellate *Paucispinifera* with elevated rim around the muscle field.

TYPES.—Holotype: USNM 149564. Figured paratype: USNM 153753. Unfigured paratypes: USNM 149565a, b. Measured paratypes: USNM 149565a, b.

COMPARISONS.—This species is of intermediate size and thus quite unlike the larger species *P. auriculata*, Muir-Wood and Cooper; *P. quadrata*, new species; and *P. tumida*, new species. It is also not comparable with the smaller new species, *P. sulcata*. *Paucispinifera costellata* can be readily distinguished from *P. intermedia*, new species, by its smaller size and much finer ornament. It is also distinguished by the same features from *P. transversa*, new species, which is similar in size to *P. costellata*. In addition to the characters mentioned, *P. costellata* differs from *P. transversa* in having a less prominent sulcus, stouter lateral spines, and in having the raised rim around the front of the muscle field.

DISCUSSION.—This is a rare species. Only one specimen is known from USNM 703 and seven from USNM 707e, a number of specimens not adequate to a full understanding of the species. No brachial interiors are known, but the interior of the pedicle valve is unlike that of any other species of *Paucispinifera*. Along the anterior side of the muscle field a ridge is formed in a curve convex anteriorly and extending from wall to wall. The distal margin of this partition is irregular and serrate. The adductor scars appear to be normal and are located in their usual position. Marks on the inside of the partition indicate that the diductor muscles were attached to it.

*Paucispinifera guadalupensis* (Girty)

*Productus guadalupensis* Girty, 1909:261, pl. 22: figs. 1, 2 [not 3, = *Yakovlevia* species]. [Not of R. E. King, 1931:61, pl. 10: figs. 9, 10, = *Yakovlevia identata*, new species.]

Girty's type lot of this species consists of three cotypes: two pedicle valves (USNM 118528a, b) from USGS 2919 (green) and the impression of a pedicle valve interior (USNM 118529) from USGS 2931 (green). The first two specimens are clearly *Paucispinifera* but the latter is a species of *Yakov-*



*levia* and, therefore is here excluded from the species. The first two specimens are very poorly preserved, but the one most by near-complete (USNM 118528a) is designated as lectotype for the species.

Paucispiniferid features of the lectotype and paratype are seen in the strongly geniculated form, poorly defined costation, transverse form, broad open sulcus, and presence of a spine row overhanging the ears. These are all external characters but they clearly indicate *Paucispinifera*.

The lectotype is widest at the hinge, with well-defined ears, strongly convex profile, but with gently swollen visceral region. The sulcus originates on the visceral disc, is rounded, moderately deep and extends to the anterior margin. Costae are variable on the specimen and number five in 5 mm on the venter. They are not so fine as illustrated by Girty.

MEASUREMENTS (in mm).—From locality USGS 2919, USNM 118528a (lectotype): length 17.8, brachial valve length ?, surface length 35.0, hinge width 33.4\*, midwidth 27.5, height 12.2, thickness unmeasurable.

STRATIGRAPHIC OCCURRENCE.—Brushy Canyon Formation (100–200 feet between top of Bone Spring and base of Getaway Member of Cherry Canyon Formation).

LOCALITY.—USGS 2919 (green).

TYPES.—Lectotype: USNM 118528a, paratype: USNM 118528b.

COMPARISON.—This species does not compare well with any of those described herein because of their poor preservation. One might expect them to compare favorably with *P. tumida*, new species, from the Getaway Member but Girty's species appears to be more finely costate, to be smaller, and not to possess the row of large spines along the posterior margin that is a conspicuous feature of the Getaway species. *Paucispinifera guadalupensis* is narrower and more elongate than *P. auriculata* Muir-Wood and Cooper; it is smaller and less robust as well as more finely costate than *P. quadrata*, new species; it is narrower and has a more swollen visceral disc than *P. intermedia*, new species. With what is known of *P. guadalupensis*, it is thus not possible to identify it with any of the larger species of *Paucispinifera*. Knowledge of its true affinities will have to await the collecting of better specimens.

DISCUSSION.—Girty likened this species to *Productus* [*Yakovlevia*] *multistriatus* (Meek) but that

is a much flatter shell on the visceral disc region and the spine pattern is completely different. Furthermore, *Yakovlevia multistriata*, as its name implies, is covered by fine costellae. This misled R. E. King 1931:67 into applying the name *P. guadalupensis* to forms that are truly *Y. indentata*, new species. One of Girty's specimens proved to belong to *Yakovlevia* and he was correct in indicating its individuality, but the other two are quite unlike *Yakovlevia*.

### *Paucispinifera indentata* (Girty)

PLATE 426: FIGURES 16–22

*Productus indentatus* Girty, 1909:259, pl. 20: figs. 15–16b.

Small, transversely rectangular in outline, hinge forming widest part and usually with prominent, bluntly pointed ears. Sides sloping medially; anterior margin deeply indented. Beak small; umbo in ventral view narrowly rounded and only slightly protruding posterior to hinge. Surface marked by distinct, but low, broadly rounded, crowded costae, about five per 5 mm on trail of adults. Spines not numerous, arranged in row of small spines along posterior margin; curved row of three spines on lateral slopes and overhanging ears; few scattered spines on trail; very few small spines elsewhere.

Pedicle valve unevenly convex in lateral profile, posterior third flattened, middle third strongly convex, anterior third gently convex; anterior profile broad, low dome, deeply indented medially and with moderately steep lateral slopes. Umbonal and visceral regions gently swollen; geniculation near midvalve; trail occupying from one-third to a half surface length. Sulcus originating on visceral disc, deep on venter and deeper still on trail; flanks bounding sulcus moderately rounded.

Brachial valve deeply concave and deepest near midvalve; sides and anterior sloping steeply toward midvalve; umbonal depression deep; ears deflected, gently concave; fold moderately strong, especially anteriorly on trail, not extending notably beyond midvalve in posterior direction.

Pedicle valve interior with adductor field oval in outline and with granulose patch anterior to it separating roundly flabellate diductor scars. Ear baffles moderately developed.

Brachial valve with small trilobed, sessile cardinal

process and well-developed zygidium. Adductor field small but moderately thickened. Ear baffles strong, closely fluted toward exterior and extended

medially to form rim around visceral region. Breviseptum short; endospines short and stout. Brachial ridges moderately well developed.

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MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USGS 2930							
118525a	10.2	?	?	14.0	4.8	?	15.0?
(lectotype)							
USNM 731							
152759a	13.0	10.2	21.6	17.2	8.0	2.9	23.5
152759b	10.4	8.8	17.2	15.5	5.8	1.9	18.5
USNM 732a							
152760a	12.2	?	19.4	18.6	8.0	2.9	23.5

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STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler Member).

LOCALITIES.—USGS 2930; USNM 731, 732a.

DIAGNOSIS.—Small, transverse, rectangular *Paucispinifera* with deep sulcus and indented anterior margin.

TYPES.—Lectotype: USNM 118525a. Paratype: USNM 118525b. Figured hypotypes: USNM 152760 a, b; measured hypotypes: USNM 152759a, b; 152760a.

COMPARISON.—This small species is compared with other small ones such as *P. costellata* and *P. sulcata*, both new, but it differs from both in being much smaller and having a narrower and deeper sulcus. Furthermore, the spines of the two Glass Mountain species are considerably stouter, although their pattern is very similar.

DISCUSSION.—This is an extremely rare species, but we were fortunate in obtaining a few good interiors that exhibit the true generic characters. The species is not related to *Marginifera*, as believed by Branson (1948: 403) because it has a zygidium. Girty (1909: 259) was correct in deducing that it was related to *Liosotella popei* (Shumard), which is one of the Paucispiniferidae.

*Paucispinifera intermedia*, new species

PLATE 426: FIGURES 32–58

Medium size for genus, transversely rectangular in outline; hinge forming widest part, bluntly pointed but large ears. Sides gently curved, sloping

medially; anterior margin broadly rounded. Surface costate, costae strongest on venter but generally subdued, sporadic on visceral disc and varying from distinct to faint on trail. Halteroid spines, generally slender, forming row along posterior margin, row of five on lateral slopes near base, one on trail near midpoint between margin and venter, and one between sulcus and lateral slope.

Pedicle valve narrowly convex, posterior or venter profile shorter than trail and nearly flat; trail forming steep slope but gently convex. Anterior profile broadly domed and steep-sided. Beak small, umbonal region smooth, only slightly convex; umbonal slopes gentle. Sulcus shallow, variable, originating just posterior to venter. Flanks bounding sulcus gently rounded but with steep slopes. Ears rounded, smooth, blunt.

Brachial valve flatly concave in posterior two-thirds, strongly geniculated, trail short; ears flattened, not strongly demarcated. Fold low, most conspicuous anterior to midvalve and strongest on trail.

Pedicle valve interior with broad, flattened ginglymus; ear baffles strongly elevated, curving as ridge to beak, and continued anteriorly from midvalve as thickened area across valve front inside of margin. Adductor platform a narrow elevated ridge; adductors long and slender; diductor scars broad and flabellate. Region anterior to adductor platform and sides ventral to ear baffles strongly endospinose.

Brachial valve interior with small lateral ridges uniting with low ear baffles; cardinal process small, narrow, and with strongly curved narrow median

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706c							
149561a	18.9	?	34.0	34.6	27.5	12.6	?
149561b	17.7	16.8	29.0	27.3	27.0	11.0	4.4
(holotype)							
149561c	18.6	?	34.0	30.3	24.9	12.7	?
149561d	16.9	14.1	27.5	27.6	25.3	10.6	5.3
149561e	17.2	?	35.0	31.8	26.1	13.0	?
149561f	20.5	?	38.0	30.3	25.5	13.2	?
149561g	17.2	?	32.0	28.0	24.6	11.6	?
149561h	19.5	?	35.5	30.4	27.7	13.3	?
149561i	15.5	14.0	26.0	24.4	24.1	9.1	2.8
149561j	15.0	13.2	23.0?	25.1	22.0	9.3?	3.0
149561k	14.3	12.9	22.0	20.0	20.4	6.7	2.4
149561l	11.9	?	13.0	11.5	14.-	2.7	?
149561m	9.4	?	10.0	9.6	11.2	2.4	?
149561n	8.4	?	10.0	8.1	9.5	2.6	?

lobe. Adductor platform moderately thick; brevisseptum low and inconspicuous. Endospines large, forming row just posterior to marginal thickening defining edge of visceral disc.

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank and Willis Ranch members).

LOCALITIES.—Word: USNM 732s. China Tank: USNM 706c, 733q. Willis Ranch: USNM 706.

DIAGNOSIS.—Small to medium *Paucispinifera* with much flattened visceral region, blunt ears, and subdued costae.

TYPES.—Holotype: USNM 149561b. Figured paratypes: USNM 149561a, i, o-r. Measured paratypes: USNM 149561a, c-n. Unfigured paratypes: USNM 149561c-h, j-n.

DISCUSSION.—The flattened visceral disc and the subdued umbo give this species a somewhat distorted appearance, as though it had been slightly crushed anteroposteriorly. As with all other species of this genus this one is variable in several respects. The ornament is not uniform, some have well-defined costae, but in others these are indistinct, perhaps because of submarine wear but this is not certain. The complement of spines is also variable, but usually remnants of those on the posterior margin and ears are preserved. The spine row on the lateral slopes is usually better preserved in this species than others of the genus. Scattered spines of fair size also appear elsewhere on the shells but no definite pattern could be determined.

Inside the pedicle valve the slender and strongly elevated ear baffle is distinctive and makes a small, triangular chamber of the ear. Also distinctive of this species is the strong development of endospines anterior to the narrow adductor platform. These are usually conspicuous because they are elevated along the ridge formed by the exterior sulcus. Endospines in a thick mat are also developed on the inner lateral walls.

The interior of the brachial valve is distinctive because of its short trail and the subdued character of the interior compared to those of *P. auriculata* and *P. quadrata*. The brachial ridges are slender and not prominent, and the ear baffles, like those of the other valve, are also slender. The endospines form a single row of fairly large spines on the edge of the trail.

GROWTH.—The smallest specimens of this species are fairly round in outline, and the hinge is narrower than the midwidth. Definite ears do not appear until the shell has attained a width of 20 mm or more. The youngest specimens have spines along the posterior margin, and the curved row on the lateral slopes also appears early. The smallest pedicle valves, about 6 mm long, are fairly convex, but the convexity is obscured by increasing growth. The extremely young cardinal process is narrowly convex and with lobes protruding anteriorly as in other species of this genus.

*Paucispinifera latidorsata* (Girty)

PLATE 217: FIGURES 1-3; PLATE 426: FIGURES 8-15

*Productus latidorsatus* Girty, 1909:264, pl. 11: figs. 11-13b.

Medium size for genus, wider than long, maximum width at hinge; sides well rounded; anterior margin broadly rounded and only slightly indented. Surface very faintly costate, costae barely visible even on trail. Sparsely spinose; few small spines on posterior margin; curved row of six or seven spines at base of lateral slopes and overhanging ears; scattered thick spines on trail; few small spines on visceral disc and venter.

Pedicle valve moderately and evenly rounded in lateral profile and narrowly domed in anterior profile, median region slightly depressed. Umbonal and visceral regions fairly strongly swollen; venter swollen; trail convex. Sulcus originating on visceral disc, broad and shallow, extending to anterior margin, which it indents slightly. Ears fairly large and laterally extended.

Brachial valve with faint radial costae especially on trail, deeply concave and with deep umbonal depression. Ears deflected, gently concave, and bounded by poorly defined oblique ridge. Greatest depth just anterior to midvalve; sides and anterior sloping steeply.

Pedicle valve interior with small ear baffles, inner ends of spines of the curved row, well displayed. Adductor track moderately thickened and with elongated, smooth adductor scars; diductor scars subflabellate.

Brachial valve interior with delicate cardinal process and narrow zygidium. Adductor field not strongly thickened; brevisseptum low, anteriorly elevated and extended. Endospines short and stubby. Brachial ridges moderately thickened; ear baffles strong.

MEASUREMENTS (in mm).—Thickness of specimen USNM 152758 is 5.9; of others, unmeasurable.

	length	brach- ial valve length	sur- face length	hinge width	mid- width	height
USGS 2926						
118534a	19.2	?	32.0	26.8*	24.3	11.0?
(lectotype)						
118534c	?	18.1	?	27.3	23.7	?
USNM 750						
151617	19.3	?	31.0	27.8*	21.6	9.2
AMNH 635						
152758	17.3	13.8	31.0	24.0	21.3	10.5

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler, Pinery, Rader, and Lamar members), Capitan Formation.

LOCALITIES.—Bell Canyon: AMNH 401. Hegler: AMNH 635; USNM 731, 732a. Pinery: AMNH 33, 398. Rader: AMNH 403; USNM 725g, 740i. Lamar: AMNH 39; USNM 725e, 728p, 738, 738b. Captain: USGS 2926; USNM 737a, 750, 750b.

DIAGNOSIS.—Medium-sized *Paucispinifera* with few or obsolescent costae and few spines.

TYPES.—Lectotype: USNM 118534a. Paratypes: USNM 118534b, c. Figured hypotypes: USNM 153952a-c. Measured hypotypes: USNM 151617, 152758.

COMPARISON.—This species is distinguished from all others by its relatively smooth exterior, the costae being obscure or obsolescent.

DISCUSSION.—Girty's type lot consists of three cotypes, all decorticated, and two pedicle valves with broken ears. The brachial valve is an impression of the exterior, preserving some patches of decorticated shell but exhibiting the ears in almost perfect condition. Of the two pedicle valves, one (118534b) is missing part of one side. Consequently, we select the larger and better preserved of the two pedicle valves as lectotype. The ears are broken on this specimen, but some traces of costae are preserved and the curved spine row is well exhibited.

Girty (1909:265) likened this species to *Productus subhorridus* Meek because of its poorly costated shell, general similarity of shape, and few spines. Girty's species shows exterior and interior characters relating it to the *Paucispiniferidae*. The curved spine row overhanging the ear is perhaps the best-defined exterior character of *Paucispinifera*. This combined with the well-formed zygidium leaves no doubt as to the generic and family characters of the species. King (1931:83) referred this species to *Avonia* but did not figure it. The specimens, which are not figured, are said to be from his locality 241 of the "Word: First limestone member on mountain north of Leonard Mountain, south-east of hill 5453." His specimens probably do not belong to Girty's species but where they should be assigned is a question.

*Paucispinifera magnispina*, new species

PLATE 208: FIGURES 1-4; PLATE 417: FIGURES 20-44; PLATE 475:

FIGURE 6

Medium size, wider than long, rectangular out-

line; hinge forming widest part. Ears prominent, triangular, pointed. Sides rounded, sloping slightly inward; anterior margin broadly rounded. Surface unevenly costate, umbonal region faintly costate to nearly smooth but venter and trail strongly and fairly evenly costate; costae three to five per 5 mm on trail. Halteroid spines forming row of four spines at base of lateral slopes; single spine on ear; two or more spines on trail. Spines on trail and youngest spine, at end of spine row at base of lateral slopes, long and extremely stout.

Pedicle valve unevenly convex in lateral profile, posterior half somewhat flattened but anterior half moderately convex. Anterior profile steep-sided dome with deep medial depression. Beak small; umbo somewhat narrowly convex, moderately swollen; umbonal slopes long and gentle. Sulcus

originating about midway between beak venter, well marked on trail, broadly U-shaped; flanks bounding sulcus well rounded and steep-sided. Ears narrowly rounded.

Brachial valve deepest at about midvalve; fold originating at midvalve, subcarinate, fairly strong. Ears well demarcated; trail steep.

Pedicle valve interior with strongly elevated ear baffles closing off ear chambers; adductor platform, strong, elongate-triangular; diductor scars subcircular.

Brachial valve interior with well-formed ear baffle continued as ridge at edge of venter on trail. Endospines large, forming row at edge of visceral region. Adductor platform moderately thickened; brevisseptum united with thick ridge from cardinal process.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706c							
149563a	20.0	15.8	40.0?	29.7	25.4	14.2	7.6
(holotype)							
149563b	20.4	?	39.0	23.7+	23.2	14.0	?
149563c	20.8	?	39.0	29.0	23.7	14.5	?
149563d	16.9	14.5	28.0	22.3	21.0	10.4	4.5
149563e	18.2	13.1	37.0	24.0	21.9	12.4	7.4

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank and Willis Ranch members).

LOCALITIES.—China Tank: USNM 706c. Willis Ranch: 706e, 723t, 724u.

DIAGNOSIS.—*Paucispinifera* of medium size, strongly but finely costate and with large thick spines.

TYPES.—Holotype: USNM 149563a. Figured paratypes: USNM 149562a; 149563b, d, e, g, h. Measured paratypes: USNM 149563b–e. Unfigured paratypes: USNM 149563c, f.

COMPARISON.—This species is best compared to *P. sulcata*, new species, from which it differs in its more domed form, thick spines, greatly thickened adductor platform of the pedicle valve, and more thickened details of the brachial valve.

DISCUSSION.—*Paucispinifera magnispina* is a rare species; only a few specimens have been found in the China Tank Member. The great strength and thickness of the spines are unusual. An undescribed

form resembling *P. magnispina*, occurring at USNM 706, is somewhat larger and differently ornamented. Its spines are thick and stout but too few specimens are available to make a description possible.

*Paucispinifera parasulcata*, new species

PLATE 244: FIGURES 30, 31; PLATE 446: FIGURES 5–10, 18–22

Medium size for genus, wider than long, hinge forming widest part; outline rectangular; sides sloping medially; anterior margin medially indented. Surface fairly regularly costellate with about five costellae per 5 mm at anterior; interspaces between costellae narrower than costellae. Spines occurring in row of three or four on lateral slopes over the ears, few along posterior margin and one on ear, at least two on each flank of trail.

Strongly convex in lateral profile, most convexity posterior to midvalve; anterior profile broad, bilobed dome deeply depressed medially and with



steep sides. Umbo slightly elevated posterior to hinge; umbonal region flattened. Sulcus wide and deep, broadly V-shaped and extending from umbonal region to anterior margin; flanks narrowly rounded. Ears small, convex, and slightly to strongly acute.

Brachial valve deeply concave, with deep um-

bonal depression; fold narrow but fairly strong, originating anterior to umbonal depression and strongest at anterior. Ears deflected, gently concave.

Pedicle valve interior with thick and elevated adductor callosity. Brachial valve with large zygidium but small cardinal process; adductor field ridges moderately thickened.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 736x							
153909a	18.3	15.0	33.0	27.5	30.4	13.0	6.0
(holotype)							
USNM 732j							
153911a	18.6	14.6	35.0	24.5	33.4	13.7	7.8
153911b	16.9	15.0	28.0	24.6	26.0?	12.4	5.8
154522	19.5	15.5	36.0	25.9	31.6*	15.0	8.0

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 721j, 732j, 736x.

DIAGNOSIS.—Strongly sulcate and strongly costellate *Paucispinifera* with very low umbo.

TYPES.—Holotype: USNM 153909a. Figured paratypes: USNM 153909b, 153911a, 154522. Measured paratypes: USNM 153911a, b; 154522.

COMPARISON AND DISCUSSION.—This species is larger and wider than *P. sulcata*, new species, and is differently ornamented. *Paucispinifera transversa*, new species, is similar but has a different lateral profile and ornament. It is also different from *P. intermedia*, new species, in having stronger ornament on the average and a much deeper sulcus. *Paucispinifera parasulcata*, like all of the tribe, is a variable species. Its ornament varies from strong to rather weak, but this may be due in part to the conditions of deposition. USNM 732j and 736x are death assemblages representing accumulations of bottom sweepings by currents. Few specimens are perfect and all show evidence of having been buffeted about.

#### *Paucispinifera quadrata*, new species

PLATE 417: FIGURES 1–5; PLATE 423: FIGURES 1–23; PLATE 424: FIGURES 1–39

*Marginifera opima* King (not Girty), 1931:87, pl. 22: figs. 21, 24a, b?, 25a, b.

*Paucispinifera auriculata* Muir-Wood and Cooper, 1960:320, pl. 122: fig. 10 [only].

Large, thick-shelled, variable in outline but generally quadrate; hinge forming widest part; ears narrow and triangular. Sides gently rounded, sloping medially; anterior margin broadly rounded and medially sulcate. Pedicle valve paucispinose, commonly with only four long halteroid spines; one on each lateral slope overhanging ear and one on each side of sulcus, on trail just anterior to venter. Spines on disc and elsewhere on trail usually small and sporadic; usually no spines along posterior margin or on ears. Beak and umbonal region smooth; visceral disc and venter strongly costellate to costate; trail of adult usually paucicostate, strong costae commonly extending from outermost spine over ear to anterolateral margin.

Lateral profile unevenly convex, visceral region gently convex, venter narrowly rounded, trail long and fairly strongly curved. Anterior profile narrowly domed, with slopes to ears precipitous. Beak small; umbonal region somewhat narrowly convex; umbonal slopes steep, posterior nearly smooth. Ears narrowly rounded, usually extended. Sulcus variable, originating between 6 and 10 mm anterior to beak; narrowly to broadly U-shaped, commonly fairly wide. Flanks bounding sulcus well-rounded, with moderately convex but steep sides.

Brachial valve deeply concave, trail forming nearly vertical wall around anterior and sides.

Umbonal region forming smooth, moderately deep concavity; ears deeply concave, demarcated by oblique ridge; posterior margin slightly elevated to form low wall along posterior. Median ridge originating just anterior to umbonal depression, low, subcarinate and extending to anterior margin.

Pedicle valve interior with thick and widening adductor platform; adductor scars located on posterior part of platform; inner scars elongate, teardrop-shaped; outer scars on side or at base of platform elongate and dendritic. Ear baffles strongly elevated, setting off triangular depression. Ear baffles internally striated, striations extending along entire lateral wall. Visceral area minutely endospinose, forming slightly thickened rim well inside

anterior and lateral margins and uniting with ear baffle.

Brachial valve in adults strongly thickened; lateral ridges usually not strongly developed, joining ear baffles. Ear baffles moderately elevated and externally strongly striated, joining thickened anterior band of small endospines defining anterior margin of visceral area. Adductor field moderately thickened in adult, strongly so in old age; inner adductors teardrop-shaped; outer adductor an irregular dendritic patch; brevisseptum thick and strongly elevated anteriorly; brachial ridges with thickened and elevated margins. Cardinal process variable, wide, with exaggerated lobes. Lophidium small; zygidium broad and thick band.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706b							
149550a	34.3	25.4	75.0	62.0	40.0?	26.0	12.8
149550b	30.5	22.8	58.0	42.8	32.5	25.0?	10.3
149550c	32.3	?	59.0	42.3	37.4	19.0	?
149550d	26.5	19.0	58.0?	40.6	37.5	22.0?	9.3
149550e	30.0	21.9	58.0	40.0	36.5	21.0	12.7
149550f	34.3	19.8	57.0	39.6	30.5	19.4	13.0
149550g	27.1	?	52.0	38.6	32.1	18.0	?
149550h	25.6	17.0	52.0?	34.8	30.2	17.6	8.5
149550i	28.0	20.0	54.0	35.4	31.2	18.8	10.6
149550j	23.3	17.0	52.0?	34.8	29.0	17.9	9.3
149550k	22.3	43.0	34.5	26.0	26.0	15.7?	7.5
149550l	19.0	36.0	29.6	25.7	25.7	14.0	5.5
149550m	18.6	16.5	29.0	30.0	27.1	11.0	4.3
149550n	18.0	15.3	27.0	29.2	24.3	14.4	3.5
149550o	17.6	15.2	26.0	22.0?	24.0	14.0	4.8
149550p	18.3	16.0	25.0	29.0	26.2	7.9	2.5
149550q	17.1	15.5	25.5	28.4	26.6	9.4	1.5
149550r	16.0	13.7	22.0	18.0?	21.7	6.9	2.4
149550s	16.0	13.7	20.0	15.3	21.0	5.5	1.0
149550t	14.0	12.6	17.0	13.9	18.8	4.5	0.6
149550u	12.8	?	16.0	9.2	16.0	3.9	?
149550v	9.6	?	12.0	8.9	11.4	3.3	?
149550w	25.4	?	50.0	37.0	28.5	17.0	?
153986a (holotype)	21.4	15.4	43.0	32.8	28.8	16.5	8.0

STRATIGRAPHIC HORIZON.—Word Formation (China Tank, Willis Ranch, Appel Ranch members, and lenses between Willis Ranch and Appel Ranch members).

LOCALITIES.—Word: USNM 741p. China Tank: USNM 726r. Willis Ranch: USNM 706. Appel

Ranch: USNM 716v. Lenses: USNM 706b, 732c, 737w, 742b.

TYPES.—Holotype: USNM 153986a. Figured paratypes: USNM 124055a; 149550e, m, r, t; 153949a, b; 153986b, 153987a-h, k, l. Measured paratypes: USNM 149550a-w.

**DIAGNOSIS.**—Large, thick-shelled quadrate *Paucispinifera* with no spines along posterior margin and a wide deep sulcus.

**COMPARISON.**—A detailed comparison of this species and *P. auriculata*, which it resembles in size, is given under that species. This is a larger species than any other yet found in the Guadalupe Mountains.

**DISCUSSION.**—Two features of the ornament of this species are outstanding: the regularity of the spine pattern, compared to that of *P. auriculata* Muir-Wood and Cooper, and the general absence of spines on the posterior margin. The spine pattern with amazing regularity consists of the two large lateral spines and the two large spines on the trail just anterior to the venter, to make a complement of four large and thick spines. No information is available as to the length of the spines. Most of the remnants preserved approach an inch in length but all are broken. Most of these are stout and thick, which leads to the suspicion that they must have been long in life.

It is not possible to say that the posterior margin is absolutely without spines, because an occasional specimen has paired spines on the ears. These are so rare that it may be said for practical purposes and specific comparison, that the posterior margin lacks spines. Young specimens show evidence of a spine row at the base of the lateral slopes as in *P. auriculata*; and few adult specimens show traces of the spine row in the presence of minute nodes, but most show no trace of its presence, only the last formed (fifth) spine having survived.

The interior details of the pedicle valve of this species are more pronounced than those of *P. auriculata*. The adductor platform is well expanded anteriorly and greatly thickened; in some specimens it stands above the valve floor for almost 5 mm. The median adductor pairs occupy most of the anterior part of the platform, but the posterolateral scars occupy the sides of the platform and a portion of the floor posterior to the expanded part. These scars are dendritic and in some specimens not clear, but in others are strongly impressed. The diductor scars, which are usually visible and frequently strongly impressed, are broadly to narrowly elliptical and are located opposite the broadest part of the platform. The area behind the diductor scars is generally smooth. The migration of the diductors

anteriorly has been sealed over by deposit of shell substance.

The ear baffles of this species form a wall separating the ear from the visceral region. The ear on the inside thus becomes a small triangular chamber. The inside of the baffle and the inner wall for some distance ventrally are strongly and obliquely striated, the striae curved in the direction of the posterior margin. The ear baffle is continued as a low ridge anteriorly, decreasing in strength in this direction.

In some specimens, however, the ridge is faint but distinct and continues across the shell toward the midline, forming a submarginal rim bounding the visceral region.

The cardinal process is variable in this species; in some specimens it is narrow and the lateral lobes small but in others it is widely flaring, with large lateral lobes. The median lobe is likewise variable; in some specimens it is long and narrow and extends posteriorly toward the zygidium, but in others it is more erect, with the myophore face well exposed posteriorly, the former suggesting the cardinal process of the Marginiferidae, and the latter, that of the Linoproductidae.

The lateral ridges of this species are not prominent, forming only a low swelling obliquely, just anterior to the posterior margin. They unite with the ear baffles which are prominent and strongly elevated posteriorly. These decline in height anteriorly and unite with a thickening around the anterior margin of the visceral disc. Endospines in the young adult are generally small, but in obese shells they are short and thick, and help to emphasize the anterior marginal thickening.

**GROWTH.**—The growth of this species is similar to that of *P. auriculata* but differs in details. The row of spines at the base of the lateral slopes is present, as are occasional spines along the posterior margin. The sulcus forms at 8 to 10 mm from the beak and is strong in half grown shells. Geniculation is not sudden; its beginnings occur at about 15 mm. The large lateral and anterior spines appear at 18 to 20 mm, and the formation of the full complement of spines might be taken as the arrival to adulthood. After 20 mm, growth is mainly anterior, the shell prior to this point being mostly much wider than long. Ears form at about the 18-to 20-mm stage, the hinge width being less than the midwidth during the earlier stages.

**PALEOECOLOGY.**—The habit of this species is not clearly known. Its occurrence at USNM 706b is clearly in a death assemblage. Most of the specimens have been rolled about, their spines usually badly broken and the ornament often somewhat smoothed by abrasion. Many of the specimens, furthermore, appear as single valves and many of these are occupied on the interior by encrusting organisms. This species is a favorite host for *Heteralosia hystricula* (Girty). The deeply concave pedicle valves and the deep recess and smooth surface of the brachial valve exterior must have afforded safe and comfortable sites for this small species.

***Paucispinifera rara*, new species**

PLATE 476: FIGURES 27–31

Fairly large for genus, quadrate in outline, posterior margin extended onto small ears; sides somewhat concave; anterior margin broadly rounded. Surface costellate, costae irregular in size, closely crowded, about four per 5 mm at anterior margin. Halteriod spines in row overhanging ears in row of small spines on posterior margin and scattered on body and trail.

Pedicle valve unevenly convex in lateral profile, with posterior third somewhat flattened, median third forming narrow curve and anterior third gently convex; anterior profile forming high, steep-sided dome with median part slightly emarginate. Sulcus shallow, originating about 10 mm anterior to beak and continuing as narrow depression to anterior margin. Beak small; umbonal region low and only slightly extended posterior to hinge. Ears smooth, narrowly rounded in section, and forming almost a right angle.

Brachial valve deeply concave, most so at midvalve; ears forming shallow concavity; umbonal region forming a shallow depression.

Interior with strong ear baffle in pedicle valve.

**MEASUREMENTS** (in mm).—From localities USNM 725h and AMNH 524, specimens USNM 155119 (holotype) and USNM 155120 (paratype), respectively: length 20.5, 22.0; brachial valve length 14.7, 19.3; hinge width 30.6, 30.4\*; midwidth 24.6, 28.7; height 14.7, 15.0; thickness 7.7, 5.0.

**STRATIGRAPHIC OCCURRENCE.**—Bell Canyon Formation (Pinery Member).

**LOCALITIES.**—AMNH 524, USNM 725h.

**DIAGNOSIS.**—*Paucispinifera* with closely crowded

costae and narrow median sulcus on the pedicle valve.

**TYPES.**—Holotype: USNM 155119. Unfigured and measured paratype: USNM 155120.

**COMPARISON.**—*Paucispinifera rara* is smaller, squarer, and has less pronounced ears than *P. auriculata* Muir-Wood and Cooper. It is smaller than *P. quadrata*, new species, has less extended ears, stronger and more regular ornament, and a shallower narrower sulcus. It is similar in size to *P. rectangulata*, new species, but has a lesser development of the sulcus and more regular costae. It is smaller and has more regular costae and a shallower sulcus than *P. tumida*, new species.

*Paucispinifera rara*, as its name implies, is an unusual species in the Bell Canyon fauna, which is generally quite deficient in Productacea.

***Paucispinifera rectangulata*, new species**

PLATE 426: FIGURES 1–7

Medium size for genus, wider than long, rectangular outline, ears widely extended but somewhat truncated distally. Sides gently rounded; anterior margin broadly rounded and anteriorly indented. Umbonal region only slightly extended posterior to hinge. Surface indistinctly costate, costae strongest on venter, becoming obscure on visceral disc and trail. About four costae in 5 mm on venter and trail. Spines few; occasional pair on posterior margin; row of three or four on lateral slopes overhanging ears; occasional spines on trail and elsewhere.

Pedicle valve unevenly convex in lateral profile, visceral disc flatly convex; venter sharply rounded, trail long and moderately convex. Anterior profile narrow dome with top strongly bilobed, sides precipitous. Visceral region only slightly swollen; sulcus originating on visceral disc, deeply and broadly V-shaped and extending to front margin. Flanks narrowly rounded.

Brachial valve deeply concave, with umbonal depression deep, deepest at midvalve; sides and trail very steep; ears strongly deflected and margined by oblique ridge; fold originating just posterior to midvalve, fairly strong and subcarinate, best shown on trail. Trail fairly strongly costate.

Pedicle valve interior not clearly known. Brachial valve interior with small trilobed cardinal process and strong zygidium; brevisseptum strongly ele-

vated anteriorly; adductor field moderately thickened; brachial ridges strong and endospines few but stout, moderately long.

MEASUREMENTS (in mm).—From locality 723w, specimen USNM 152761a (holotype): length 22.8, brachial valve length 16.9, surface length 43.5, hinge width 33.6, midwidth 27.3, height 15, thickness 6.9.

STRATIGRAPHIC OCCURRENCE.—Word Formation (Willis Ranch Member).

LOCALITY.—USNM 723w.

DIAGNOSIS.—Medium size *Paucispinifera* with very sharp geniculation and strongly rectangular outline.

TYPES.—Holotype: USNM 152761a. Figured paratype: USNM 152761b.

COMPARISON.—This species suggests *P. auriculata* Muir-Wood and Cooper, *P. transversa*, new species, and *P. intermedia*, new species, but it is narrower than these, the umbonal region is more flattened, the geniculation is narrower, and sulcus deeper. Its abrupt lateral slopes and sparse, scattered spines are other distinctions.

DISCUSSION.—This species is rare but distinctive enough to be named despite the small amount of material available.

### *Paucispinifera spinosa*, new species

PLATE 417: FIGURES 6–19

Medium size, wider than long, generally elliptical in outline; ears large and extended, making hinge width greater than midwidth. Sides rounded; anterior margin broadly rounded but only slightly indented medially. Surface irregularly costate; costae strongest on sides, venter, and trail, nearly absent on visceral disc. Costae numbering two or three in 5 mm on trail. Spines numerous; one to several on posterior margin; curved row on lateral slopes, usually numbering three to five, overhanging ears, attaining length of 28 mm; numerous spines of two sizes on trail and scattered small spines elsewhere.

Pedicle valve fairly evenly convex in lateral profile, with visceral disc moderately flattened and trail flatly convex and steep; anterior profile a broad dome with median depression and steep sides. Umbonal region narrowly but slightly protruding posterior to hinge. Sulcus variable, usually shallow and extending from anterior side of visceral disc

to front margin. Flanks moderately rounded.

Brachial valve fairly strongly concave, costate on trail; umbonal depression deep; ears not strongly deflected.

Pedicle valve interior with strong ear baffles and slightly thickened adductor field. Brachial valve interior with small cardinal process covered by zygidium and strong lophidium on dorsal side. Adductor field slightly thickened; ear baffles fluted, moderately strong, in some specimens continued as low band around visceral disc.

MEASUREMENTS (in mm).—Brachial valve length, and thickness, unmeasurable.

	length	surface length	hinge width	mid- width	height
AMNH 398					
152769a (holotype)	15.8	30.0	?	21.0	10.4
152769b	15.7	28.0	27.4*	23.6	8.3?
152769c	14.8	25.5	21.4*	20.2	9.6
152769d	15.3	30.0	19.4	20.0	8.7

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler and Pinery members).

LOCALITIES.—Hegler: USNM 731. Pinery: AMNH 398; USNM 733.

DIAGNOSIS.—Medium-sized *Paucispinifera* with relatively strong costae and numerous spines on the trail.

TYPES.—Holotype: USNM 152769a. Figured paratypes: USNM 152769b, e; 153950. Measured paratypes: USNM 152769b–d. Unfigured paratypes: USNM 152769c, d.

COMPARISON.—This species is unlike any of those from the Glass Mountains and it is best compared with *P. suspecta*, new species, from the Guadalupe Mountains, from which it differs in being slightly smaller, in having stronger costae, and in having more spines on the trail.

DISCUSSION.—The material on which this species is based is not as well preserved as some of the Guadalupe specimens. Nevertheless, the characters are clear, and the abundance of spines unusual in the genus. Some of the specimens suggest *Echinauris*, but the costation is too strong and the spinel row on the lateral slopes is unlike that of the latter genus. Some of the brachial interiors do not have a zygidium, but this is believed to be because of poor preservation. In specimens lacking the zygidium the lophidium is revealed in all its strength.



*Paucispinifera sulcata*, new species

PLATE 418: FIGURES 1–51; PLATE 426: FIGURES 23–26; PLATE 475: FIGURES 21, 22

Small, variable, transversely subrectangular in outline, greatest width at hinge. Ears triangular, prominent. Sides gently convex and sloping medially; anterior margin broadly rounded, indented by sulcus medially. Surface costellate to costate, ribs varying from five to seven per 5 mm on venter. Costae strongest on sides and trail, becoming finer or obsolete in posterior third. Spines in adults usually consisting of large spine on ear; row of three spines at base of lateral slopes with last one largest and longest; two or more large spines forming crude row about midway on trail; scattered but rare small spines elsewhere. Spines attaining maximum length of 50 mm.

Pedicle valve strongly but unevenly convex in lateral profile, posterior third slightly flattened but anterior two-thirds strongly rounded. Anterior profile strongly domed, with precipitous sides and broadly and deeply indented posterior margin. Beak small, umbonal region smooth, gently swol-

len. Visceral region moderately swollen. Ears usually bluntly rounded distally. Sulcus originating just posterior to venter, usually broad and deep but variable, extending to anterior margin. Flanks bounding sulcus usually narrowly rounded.

Brachial valve deeply concave, deepest at midvalve; ears well demarcated, moderately concave in external view. Umbonal region a deep rounded depression anterior to fold which appears near midvalve; fold fairly strong, broadly to narrowly subcarinate; trail steep. Entire valve except ears and posterior quarter costellate to costate.

Pedicle valve interior with adductor platform thickened only in late adulthood, thickening variable, usually widening anteriorly and with elongate adductor scars posterior to strongest thickening. Diductor scars subflabellate. Ear baffles small, low and inconspicuous, extended anteriorly to form obscure submarginal ridge. Regions lateral and anterior to muscle field coarsely endospinose.

Brachial valve interior with delicate structures; cardinal process small, with triangular myophore and well-formed zygidium and lophidium. Lateral

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702c							
149567a	18.8	13.4	36.0	29.4	23.0	12.3	6.0
149567b	17.4	14.5	31.0	26.5	22.2	12.3	4.0
149567c	18.4	14.8	34.5	26.4	23.6	13.0	4.7
149567d	19.3	13.7	33.0	28.4	21.5	11.9	4.4?
149567e	18.0	15.2	32.5	24.9	23.2	12.1	4.7
149567f	18.3	12.5	36.0	23.6	23.0	12.6	4.7
149567g	17.3	13.7	34.0	23.5	21.7	11.4	3.7
149567h	16.8	14.8	34.0	29.5	23.2	11.3	4.2
149567i	15.8	14.2	31.0	27.2	23.2	10.9	2.7
149567j	17.1	14.0	30.0	26.2	22.2	12.2	3.4
149567k	16.8	12.8	32.0?	22.0	19.3	12.3	4.7
149567l	15.2	11.9	29.0	25.4	19.9	10.4	3.0
149567m	16.1	13.3	30.0	25.0	20.8	11.5	3.1
149567n	15.2	13.1	28.0	25.0	19.4	9.9	2.9
149567o	15.0	12.9	26.0	23.0	19.8	8.2	2.4
149567p	13.8	11.8	22.0	23.1	19.6	8.2	2.2
149567q	13.4	11.6	20.0	18.3	17.9	5.7	1.9
149567r	12.4	11.6	17.5	16.4?	16.1	4.7	1.7
149567s	11.6	10.5	14.0	14.0	13.9	3.9	1.1
149567t	10.8	?	14.0	13.0	14.1	4.4	?
149567u	8.5	?	10.0	9.4	10.3	2.4	?
149566h	16.4	14.0	33.0	25.9	21.0	10.0	?
(holotype)							

ridges indistinct or slender, uniting with low ear baffles and extended anteriorly as low ridge on slope of trail anterior to endospine row. Adductor platform small, moderately thickened; endospines in one or more irregular rows at edge of visceral disc. Brevisseptum slender.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—AMNH 503, 507, 509; USNM 700v, 702c, 703a, 703c, 703d, 706f, 707e, 710u, 716x, 719x, 720d, 721j, 721o, 721s, 721t, 721y, 721z, 722e, 723x, 724a, 724b, 724c, 724j, 726d, 726z, 726za, 732j, 736x.

DIAGNOSIS.—Small *Paucispinifera* with numerous costae and a wide, deep sulcus.

TYPES.—Holotype: USNM 149566h. Figured paratypes: USNM 149566a–d, f, g, i, k–p; 149567a, m, r; 153926a–c; 155049. Measured paratypes: USNM 149567a–u. Unfigured paratypes: USNM 149567b–l, n–q.

COMPARISON.—*Paucispinifera sulcata* is so much smaller than *P. auriculata* Muir-Wood and Cooper and *P. quadrata*, new species, that no comparison of them is necessary. This species is also so much less transverse than *P. transversa*, new species, that separation is easy, although the two species are nearly the same size. *Paucispinifera intermedia*, new species, is somewhat larger than *P. sulcata* and the proportions of the two species are quite different. The ears of *P. sulcata* are smaller, the sulcus is more prominent, and the ornament significantly different.

DISCUSSION.—The spines, as in all productids, are an important feature lending specific as well as generic character. For convenience of discussion the spines of *P. sulcata* may be grouped into hinge spines, lateral slope spines, and body spines. In the adult usually only two spines are preserved along the posterior margin. These are generally located on the ear, just a short distance from the tip. A few adults preserve remnants of the first formed hinge spines on each side of the umbo. These are usually slender and short and must have been of little use to the adult.

In *P. sulcata* the row of spines at the base of the lateral slopes usually consists of three spines. As in the other species some specimens preserve only the last and largest of these spines which is the one of most use to the adult as it occupies an important position on the shell. The other two spines may or may not be preserved. All of them are rarely

preserved, because the first ones are slender and delicate.

The body spines, those of the visceral disc and trail, are the most varied in arrangement and position. In most species of *Paucispinifera* two prominent and long spines occupy the trail and are located about midway between venter and margin and on each side of the sulcus. Many specimens of *P. sulcata* are provided with spines so placed but in many of them these spines are located farther laterally and in some they appear not to have formed. A few specimens have several spines in a horizontal row at about this position and still others have large spines located anteriorly or posteriorly to these important two. Body spines posterior to the venter are usually small and some are survivors from youth. Generally spines anterior to the two basic spines of the trail are large and stout.

Another variable feature of this species is its costation, which changes from costellae to costae, and most specimens are provided with ribs of both grades. In this species, as in *P. quadrata*, new species, the major spines may produce a strong costa on their anterior side. This prominent rib is most commonly developed anterior to the last spine in the curved row at the base of the lateral slopes. In some specimens, ribs the size of costellae predominate and thus give a much different appearance than those where the predominant ribbing is of the grade of costae. No valid means of separation on the basis of ornament was found, however.

The interior characters of this species are less thickened than those of the species higher in the Word. Except for the cardinal process and associated structures, none of them seem worthy of special note. The cardinal process of most productids is variable; a specimen of adult size may have a cardinal process with juvenile characters, and the reverse may be true. So it is with the cardinal process of *P. sulcata*. Young specimens have an extremely narrow cardinal process, the posterior face forming an elongated triangle, the tapering apex of which is the lophidium. Viewed from the anteroventral side, the cardinal process is narrowly bilobed. The lobes are emphasized by a deep indentation and are commonly elongated in an anterior direction. The indentation between the lobes extends posterior for some distance in the young shells and terminates at the distal end of the median

lobe of the process, which is usually elongated posterodorsally.

The adult cardinal process is narrow and triangular when viewed from the posterior side. The lateral lobes are slender and considerably elevated; the median lobe is narrow and generally lies between them and, in some, it is partially covered by them. In other specimens the median lobe is wide and not deeply indented, virtually closing the space between the lateral lobes.

The zygidium is not formed in most young shells although some precocious individuals exhibit its beginning or, uncommonly, its full formation. Furthermore, a few adult specimens have been seen in which this yoke has not formed, or was not preserved. The collection of dorsal valves is too small to show at what stage the zygidium commonly formed.

The zygidium is a secondary structure and is deposited between the apex of the young cardinal process, which is the lophidium and the myophore of the cardinal process. A few specimens exhibit a partly formed zygidium, the best of which is on a well-geniculated adult.

The adductor field of this species deviates somewhat from that of other species. In the young the median scars are elongate and tear-shaped but are not divisible into two scars. The outer scars lie outside the median two and are usually separated from them by a low ridge. The median scars are likewise separated by a low ridge which joins or partly conceals the posterior end of the brevisseptum. With age the median scars become elevated on shell tissue, but the outer scars continue to lie outside and below them. In extreme old age (one specimen only) the median scars appear to be divisible into two parts, as in the Word species *P. auriculata* and *P. quadrata*. The outer scars do not show a dendritic pattern in any of the specimens, including the obese one mentioned above.

**GROWTH.**—The smallest specimen thought to belong to this species is 4 mm long. It, like most of the other small specimens in the collection, shows evidence of attachment spines in the umbonal region. Some small specimens have a distinct cicatrix of attachment and one specimen shows a portion of the host shell attached to the cicatrix and partly to a ring of spines. The attachment spines are very small, usually short, and are confined to the beak and umbo. In some specimens the first spines of

the rows on the posterior margin which appear on each side of the beak curve toward each other to form a ring of attachment. Spines formed later, especially the first spines of the row at the base of the lateral slopes, may also form a ring. Two or more rings of attachment may be formed. Attachment rings have been observed on specimens up to 11 mm in length.

The spines on the small specimens are frequently of considerable length. A specimen only 4 mm long has the second spine of the row at the base of the lateral slope 10 mm long. Probably all the early formed spines were of considerable length because the young *Paucispinifera* would need protection as soon as it broke loose from its mooring rings. The long, slender spines would have helped the specimen obtain stability wherever it settled.

**VARIATION.**—The variability of the costae and costellae has been noted. This species is also variable in shape, as is to be expected of specimens forced to live under conditions that are not always hospitable. Variation appears in the proportions of the shell and also in the development of the sulcus. The length-width ratio varies from 0.58 to 0.77 in adult specimens 15 mm or more in length. No correlation between these ratios and the nature of the ornament was established.

The sulcus varies, in section, from narrow and deep and V-shaped to wide and shallow and broadly U-shaped. Although these are the extremes, all degrees in between can be seen. In any case the sulcus generally forms a very conspicuous part of the shell and this fact makes the name *sulcata* appropriate.

### *Paucispinifera suspecta*, new species

PLATE 425: FIGURES 18–31

Medium size for genus, wider than long, rectangular to elliptical in outline; lateral margins rounded and indented medially. Umbonal region slightly protruding posterior to hinge; ears moderately extended laterally, large. Visceral disc region with indistinct radial markings; venter and trail marked by irregular, poorly defined costae, 3 or 4 per 5 mm on venter. Spines scattered, usually strong; forming curved row of six large spines on slopes over ears; occasional spines on posterior margin; few spines, up to five large ones, on trail; scattered, short, fine spines elsewhere.

Pedicle valve in lateral profile with flattened visceral disc region, narrowly geniculated venter and moderately rounded trail; anterior profile high dome with steep sides and gentle median indentation. Sulcus originating on anterior side of visceral disc, variable, moderately deep to shallow, extending to anterior margin. Flanks moderately swollen.

Brachial valve deepest just posterior to trail, umbonal depression deep; ears not strongly demarcated. Fold low and inconspicuous, extending beyond midvalve in posterior direction.

Pedicle valve interior with adductor field moderately thickened and elevated; ear baffles moderately strong, fluted; inner projections of spines not strong.

Brachial valve interior with small and narrow trilobed cardinal process with delicate but well-formed zygidium and small lophidium. Adductor scars moderately thickened, anterior pair smooth; outer pair not easily seen. Ear baffles only slightly formed; brevisseptum low; brachial ridges faintly defined.

MEASUREMENTS (in mm).—Brachial valve length, and thickness, unmeasurable.

	length	surface length	hinge width	mid- width	height
USNM 736					
152768a	17.6	40.0	23.6?	25.0	15.4
(holotype)					
152768b	18.2	32.0	30.0*	26.0	10.6
152768c	16.3	38.0?	26.6*	23.5	13.3

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Pinery Member).

LOCALITIES.—USNM 733, 736.

DIAGNOSIS.—Weakly ornamented *Paucispinifera* with strongly flattened visceral disc region.

TYPES.—Holotype: USNM 152768a, Figured paratypes: USNM 152768b, e, f. Measured paratypes: USNM 152768b, c. Unfigured paratypes: 152768c, d.

COMPARISON.—This species is smaller, less transverse, and less distinctly ornamented than the Glass Mountains species but it is also unlike either of the Guadalupe species. It is much smaller than *P. tumida*, new species, and more finely ornamented; it is differently shaped and more strongly ornamented than *P. latidorsata* (Girty) and is totally unlike *P. indentata* (Girty); although it resembles *P. spinosa*, new species, it is less strongly costate, larger, and less spinose on the trail than that species.

DISCUSSION.—We do not have an abundance of this species and the specimens used for measurement are all imperfect. Nevertheless the species is so clearly unlike any other form in the collection that it was thought best to name it. The species is evidently rare because we have it certainly from only one locality and doubtfully from one other. Specimens from the Pinery Member at USNM 733 are tentatively placed here but, although having the irregular ornament that suggests this species, they are generally smaller.

### *Paucispinifera transversa*, new species

PLATE 419: FIGURES 1–43

Medium size, transverse, hinge forming widest part; sides sloping strongly toward midvalve; anterior margin broadly rounded, indented by sulcus; ears large and triangular; costellae strong on venter, numbering from 3 to 5 per 5 mm, becoming fine or obsolete on anterior part of trail. Spines of halt-eroid type only, appearing in row along posterior margin, last one strongest, and occupying ear; others usually small or preserved only as bases; one (occasionally two) appearing on lateral slope and one on each side of sulcus about midway on trail of adults. Random spines scattered distantly on trail, visceral region, and slopes.

Pedicle valve narrowly convex in lateral profile, posterior half gently convex, but anterior half or trail moderately convex. Anterior profile broadly domed, with steep lateral slopes. Beak small, smooth umbonal region with faint costellae. Sulcus originating about 5 mm anterior to beak, moderately deep, broadly U- or faintly V-shaped, extending to anterior margin. Umbonal slopes long and moderately steep. Flanks bounding sulcus rounded; anterior slope steep.

Brachial valve deeply concave and strongly geniculated, deepest near midvalve in adults; ears well demarcated, deeply concave. Fold low, subcarinate, originating anterior to umbonal depression. Trail steep and long in adults.

Pedicle valve interior with adductor platform elevated only anteriorly and with the adductor scars recessed posterior to elevated part of platform. Diductor scars broadly elliptical in outline. Ear baffles not strongly developed.

Brachial valve interior with small rounded cardinal process, well-formed zygidium and small car-

inate lophidium. Adductor field slightly thickened; lateral ridges slender and extending obliquely to join low ear baffles. Brevisseptum low, except at

distal end. Brachial ridges moderately well formed. Endospines forming thick band separating visceral disc from trail.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706							
149558a	14.6	10.8	29.0	28.6	22.6	10.3	5.6
149558b	16.0	13.0	26.0	33.8	24.0	9.7	3.8
(holotype)							
149558c	16.3	?	24.0	28.0	23.1	9.5	?
149558d	17.5	?	32.0	33.6	25.6	12.2	?
149558e	16.3	13.6	29.0	30.8?	25.0	10.7	5.6
149558f	15.8	13.6	26.0	29.6	24.0	10.2	4.8
149558g	16.1	?	24.0	28.2	23.3	8.1	?
149558h	14.3	11.3	25.0	27.3	20.9	9.6	5.4
149558i	15.9	13.8	24.0	27.8	21.0	9.0	5.0
149558j	16.0	13.2	28.0	32.2	26.0	10.9	5.0
149558k	18.9	14.6	36.0	32.3	25.4	13.3	6.0

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation, Word Formation (China Tank and Willis Ranch members and lens above the latter).

LOCALITIES.—Road Canyon: USNM 716xa, 721j. China Tank: AMNH 506; USNM 706c, 713. Willis Ranch: 706, 723t, 724u. Lens: 706b.

DIAGNOSIS.—Small to medium *Paucispinifera* with the width at the hinge nearly twice the length, with fairly strong costae.

TYPES.—Holotype: USNM 149558b. Figured paratypes: USNM 149558a, c-e, l-o; 153992. Measured paratypes: USNM 149558a, c-k. Unfigured paratypes: USNM 149558f-k.

COMPARISON.—This species does not compare with *P. quadrata*, new species, which is a squarish, thick-shelled form. Comparison is best with *P. auriculata* Muir-Wood and Cooper. The spine row on the posterior margin and ears is a feature like that of *P. auriculata* but the proportions of *P. transversa* are much different, the spines are more delicate and the costation appears stronger. *Paucispinifera transversa* suggests a small edition of *P. auriculata*. Internally the two species also differ: the structures of *P. transversa* are not so strongly thickened in the brachial valve and the cardinal process appears rounder and generally smaller. Inside the pedicle valve the adductor platform of *P. transversa* is not thickened posteriorly as it is in *P. auriculata*. Furthermore, the ear baffles are not so strongly ele-

vated as in the latter species. This species is wider and shorter than *P. intermedia*, new species, and is less strongly and less completely costate.

DISCUSSION.—This is not a common species and appears in the lower part of the Willis Ranch Member of the Word Formation, where it occurs with *Enteleles*. Like *P. auriculata* the development of the spines in this species is very variable. Most specimens have the row along the posterior margin preserved as broken stubs, for, in most of the adults, only the outermost spine of the row could have been functional. None of the specimens preserves the full length of the spines but the longest complete spine preserved on the ear of one individual is slightly more than a half inch (13 mm). It is likely that the main halteroid spines on the shell body were considerably longer.

*Paucispinifera tumida*, new species

PLATE 425: FIGURES 1-17

Large, transversely subrectangular in outline, hinge forming widest part; sides gently rounded; anterior margin broadly rounded; ears large and triangular. Surface costate, costae irregular and generally subdued, numbering about 3 in 5 mm on venter. Spine arrangement irregular; a row along the posterior margin; curved row along base of lateral slopes, with last spine of row long and



stout; several spines on trail, with one on each side of sulcus most prominent; scattered small spines on visceral disc.

Pedicle valve with tumid and rounded lateral profile, posterior half slightly flattened but anterior half fairly convex. Anterior profile broadly domed with steep sides. Beak small but umbonal region moderately swollen. Venter strongly swollen and tumid and with lateral slopes swollen and steep. Sulcus shallow, not conspicuous, originating just posterior to venter. Flanks bounding sulcus well rounded, ears large, somewhat flattened.

Brachial valve moderately concave, umbonal and median regions deeply concave; ears demarcated by flattening of shell. Fold low, not well defined, originating near midvalve.

Pedicle valve interior with short, wide ginglymus. Ear baffles prominent, separating off ears. Diductor scars flabellate; adductor field only slightly thickened but elevated anteriorly; adductor scars elongate. Sides and anterior striated.

Brachial valve interior with strong lateral ridges and ear baffles curving into densely endospinose zone at edge of visceral disc and on trail. Cardinal process large but narrow; zygidium and lophidium well developed. Adductor platform low, not strongly thickened. Brachial ridges well developed; brevisseptum strong.

MEASUREMENTS (in mm).—Thickness of holotype 7.7; of others, unmeasurable.

	brach- ial		sur- face	hinge	mid-	
	length	length	length	width	width	height
USNM 728						
149555a	26.2	?	49.0	41.9	34.9	19.0?
149555b	24.6	?	42.0	37.8	34.0	16.0
149555c	20.8	?	36.0	34.0	28.7	12.0
149555d	18.8	?	26.0	27.0	26.8	9.0
149555f	?	20.7	?	?	31.3	?
149555h	25.5	21.2	54.0	44.8*	36.4	17.8
(holotype)						

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member).

LOCALITIES.—AMNH 21, 496, 512, 519, 600; USNM 728, 730.

DIAGNOSIS.—Transverse *Paucispinifera* with subdued costae, tumid venter and trail, and several large spines on the trail.

TYPES.—Holotype: USNM 149555h. Figured paratypes: USNM 149555a, g, i. Measured hypo-

types: USNM 149555a–d, f. Unfigured paratypes: USNM 149555b–f.

COMPARISONS.—This species is best compared to *P. auriculata* Muir-Wood and Cooper and *P. quadrata*, new species, because its average dimensions fall between the averages of these two species. *Paucispinifera tumida* is less transverse than *P. auriculata* but more so than *P. quadrata*. Compared to *P. auriculata* the Guadalupe species has a more costate and more tumid trail, the venter is more evenly swollen and the geniculation, therefore, not so abrupt as that of *P. auriculata*. The sulci of the two genera are similar, but that of *P. tumida* is somewhat shallower. The important difference in this feature is that the sulcus of *P. auriculata* extends farther posteriorly toward the beak and thus indents the venter strongly and gives a deep indentation in the anterior profile of the Glass Mountains species.

Other external distinctions between these two species appear in the greater abundance of spines in the Guadalupe species, even though the basic generic pattern is the same. *Paucispinifera tumida* has more spines on the trail than *P. auriculata* and the spine row on the posterior margin appears better developed in the former. The ears of *P. auriculata* are more convex than those of *P. tumida*, but their extension appears the same in both species.

Differences between the two species can be seen in the interior as well as the exterior. The adductor platforms of both valves of *P. tumida* are much less developed. Although *P. tumida* is a large species, attaining a size as great as that of *P. auriculata*, the adductor platform of the pedicle valve is scarcely thickened and in many specimens, apparently adults, no thickening has developed.

The proportions and ornament of *P. quadrata*, new species, are so different from those of *P. tumida* that the two are not likely to be confused. The sulcus of *P. quadrata* is more prominent and deep than that of *P. auriculata* and therefore makes a strong contrast with the shell of *P. tumida*, and its anterior profile is more deeply indented than that of *P. tumida*. The interiors of the two genera are also very different, that of *P. quadrata* is characterized by heavy thickening of all the structures in both valves, thus a ready means of distinction.

DISCUSSION.—The feature of this species requiring further mention is the spines. The basic spine

pattern is clearly that of the genus, with a row along the posterior margin and a curved row at the base of lateral slopes, the outer spines of each row being the largest. The unusual character is the large spines that appear on the trail in addition to the basic two of the generic pattern.

### *Paucispinifera* species indeterminate

Several specimens and lots of *Paucispinifera* have not been placed with species described above, and some of them are so distinctly different that several new species are indicated. Until more abundant material is obtained these cannot be described. A few notes, however, on specimens from some of the localities of importance are listed below.

USNM 702: A single pedicle valve (USNM 152763) referable to *Paucispinifera* is the only one that we have from the Cathedral Mountain Formation. It is 20 mm long by 29 mm wide, with well-developed ears having strong baffles. The exterior is vaguely but definitely costated as usual in the genus. The adductor track is thick and elevated. A spine row overhangs the ears and a large spine occurs on each side of the trail.

USNM 723w: Four apparently different species appear at this locality beside the described *P. rectangularata*, new species. One specimen (USNM 152764), the widest *Paucispinifera* yet found, measures 22.8 mm in length and 47.2 mm across the hinge; it is geniculated like *P. rectangularata* and is fairly strongly sulcate. Another species (USNM 152765) is squarish in outline, fairly evenly rounded in profile, and faintly costate. A third species (USNM 152766) is strongly and evenly costate but has a wide hinge and narrowly tapering acutely pointed ears. A fourth species (USNM 152767) suggests *P. sulcata*, new species, but, although delicately costate, is more swollen.

USNM 719z: An enormous but badly crushed species (USNM 155041) measuring 28 mm long by 47 mm wide at the hinge. The ornament is vague.

USNM 750a: A large bulbous *Paucispinifera* with strong costae. Measurements (in mm) of USNM 155040a are: length 23.6, surface length 42.0, hinge width 32.6+, midwidth 32.7, height 16.0. The specimens have scattered spines but few in number and the spines appear to be of small size for so large a species. The specimen (USNM 118531) figured by Girty as *Productus occidentalis*

Newberry is a *Paucispinifera* and may belong with this species.

AMNH 410: In shape and size these (USNM 155038) strongly suggest *P. latidorsata* (Girty), but they are distinctly and fairly strongly costate.

AMNH 369: A fragmentary specimen (USNM 155039) of a large vaguely costate species having a length of 20 mm and a width at the hinge of 37 mm. The specimen is noteworthy because it comes from the Bone Spring Formation.

AMNH 678: A thin-shelled and delicate species (USNM 155043) from the Cutoff Member of the Bone Spring Formation.

MEXICO: A large, undescribed species (USNM 155042) occurs in the *Waagenoceras* zone one mile south of Malascachas at the section at Las Delicias, Coahuila, Mexico.

AMNH 417: The McCombs member of the Bell Canyon Formation has a small species (USNM 155037) of poorly costate *Paucispinifera*.

### *Polymorpharia*, new genus

Large, misshapen, wide-hinged but with hinge less than midwidth; sides variable, but anterior margin broadly rounded. Ears aborted to enormous. Deeply concavo-convex in adults, but shallow to nearly plano-convex in young. Surface obscurely but coarsely costellate. Spines in row along posterior margin and in curved row at base of lateral slopes.

Pedicle valve interior with flattened interarea and callus thickening in notch at apex; ears wide, pitted. Diductor scars broadly flabellate; adductor field narrowly elongated, slightly thickened in adults. Region anterior to muscle field strongly granulose.

Brachial valve interior with lateral ridges moderately strong, obliquely joining ear baffles to form ridge around visceral region. Adductor platform somewhat thickened; each inner adductor bilobed; outer adductors obscure, elongate, and dendritic. Cardinal process variable, as in *Paucispinifera* with prominent median lobe and strongly developed zygidium. Brachial ridges thickened; brevisseptum slender.

TYPE-SPECIES.—*Polymorpharia polymorpha*, new species.

DIAGNOSIS.—Compressed and misshapen *Paucispiniferidae*.

COMPARISONS.—The exterior of *Polymorpharia*

suggests *Institella* but the ornamentation and interior characters link it to *Paucispinifera*. It differs from the latter in the form of the valves, the numerous spines on posterior margin, and the enormous development of the ears. A definite link to *Paucispinifera* appears in the row of spines along the base of the lateral slopes and in the type of cardinal process, with its strong zygidium.

**DISCUSSION.**—The most distinctive character of this genus is its variable form, some specimens having enormous ears but others have the ears aborted or distorted. The pedicle valve is extremely deep but the brachial valve fits into the pedicle valve very closely with only a little space for the viscera. The faint costellation suggests some species of *Paucispinifera*. Two other features of the exterior are distinctive, the spines and the interarea.

The collection of this species is not large and it seems to be a rare form. Broken spines, and holes representing their position, indicate a row of three spines at the base of the lateral slopes in the same position as the row in *Paucispinifera*. The most conspicuous spines are those along the hinge, some of which are on the posterior margin but others located a short distance anterior to the margin. The length of these spines is not known and it is not clear whether they are halteroid or rhizoid. On the specimens available no spines or bases were detected to demonstrate the presence of spines on the visceral disc or trail.

The posterior margin of the pedicle valve between the beak and the ears is flattened or slightly curved to produce the appearance of an interarea. When both valves are joined this flattened region extends beyond the posterior margin of the brachial valve. If this flattened region were a ginglymus rather than an interarea, part of the brachial valve would cover it.

Although the exterior of this genus is unusual and intriguing, the details of the interior are of even more interest. Inside the pedicle valve the muscle field occupies about the posterior half, with broad, flabellate diductor scars. The adductor field is long and narrow and slightly elevated anteriorly. The inner scars are bipartite; the outer scars are indistinct but are not dendritic. Anterior to the muscle field the entire inner surface is coarsely granular, with the coarsest granules located between the diductors and the valve wall. Ear baffles are not differentiated, the ears being

large, flat expansions, marked by scattered deep pits. The slopes ventrad of the ears are striated for a short distance in that direction and the striation continues anteriorly and part way around the curve toward midvalve. The "interarea" defines a delthyrium at the apex under the beak, the floor and sides of which are thickened by callus.

The brachial valve is shallow from the exterior and has a short trail. Inside, the lateral ridges are well developed and extend anterolaterally to join strong ear baffles, which are striated strongly along their outside face. The ear baffles continue as a ridge anteriorly and medially around the visceral region. The cardinal process is like that of *Paucispinifera*, having three lobes, the median one strongly cleft medially and extending posterodorsally between the lateral lobes. The zygidium is enormously developed and forms a thick loop almost obscuring the cardinal process in some specimens.

The adductor field is somewhat thickened, at least the median pair of scars are. Each scar of this pair is divided into two lobes, each lobe elongate and somewhat tear-shaped. The inner lobes of each scar are the longer and are separated by the proximal end of the brevisseptum. The outer lobes are shorter and meet the posterior end of the inner lobes at a low angle, making each pair of scars a small triangle. The outer scars of the adductor field are somewhat dendritic, obscure, and difficult to define.

The brevisseptum originated between the inner lobes of the inner pair of adductors and extends anteriorly nearly to the end of the visceral region, where its distal extremity is pointed and free. The brachial ridges are prominent and much thickened, especially on the side facing midvalve. The inner surface of the ear is broad and flat and strongly granulose, in opposition to the pits of the ear of the pedicle valve. The region between the ear baffles and muscle field is deeply and densely pitted. Endospines occur at the edge of the slope where the visceral region descends to the trail but are small and inconspicuous.

**PALEOECOLOGY.**—From the material available, it is difficult to be sure what the life habits of this genus were. The fairly dense row of spines along the posterior margin and adjacent to it, together with a possible interarea, suggests that it may have been attached in a manner similar to that of *In-*

*stitella*. On the other hand it could have lived free on the bottom, steadied by long, halteroid, hinge spines.

Specimens possibly belonging to this genus occur in the Glass Mountains at USNM 706 and 724u. In the Guadalupe Mountains specimens occur at the type-locality and at AMNH 497.

*Polymorpharia polymorpha*, new species

PLATE 427: FIGURES 1-26; PLATE 464: FIGURES 27-29

Large, variable in outline and profile, hinge wide but equaling midwidth; ears huge, winglike, when present. Sides truncated to narrowly rounded; anterior margin broadly rounded. Surface multicostate, costae numbering about 6 in 5 mm on venter. Spines in row on posterior margin and slightly anterior to it, and another row of three spines at base of lateral slopes.

Pedicle valve variable in profile with posterior half to two-thirds strongly flattened but anterior half to third strongly geniculated. Anterior profile broad dome with moderately steep sides. Beak small, umbo gently swollen, and with long gentle umbonal slopes. Visceral region flatly convex, with moderate slopes to ears; anterior narrowly folded to form trail of variable length, in some specimens greater than region posterior to venter, in others much less. Trail steep. Sulcus shallow and obscure.

Brachial valve gently concave except near angle of geniculation which is deepest part. Umbonal region shallowly depressed pit. Ears well-demarcated and flattened, defined by low ridge. Fold low, broad, indistinct.

Interior as defined for genus.

MEASUREMENTS (in mm).—Brachial valve length of holotype 19.7; of others, unmeasurable.

	length	sur- face length	hinge width	mid- width	height	thick- ness
USNM 728						
149449a	22.0+	40.4	33.4	42.8	?	4.6
149449b	24.4	39.0	32.3	35.7	10.7	?
149449c	26.4	36.5	19.3	36.0	12.2	?
149449d	25.0?	42.0?	39.0?	50.6	18.6	?
149449e	26.0	?	35.0	38.6	12.0?	?
149449f	23.2	30.0	19.4	31.6	7.9	?
149449s	23.6	?	40.6	38.2	14.0?	5.1
(holotype)						

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation, Cherry Canyon Formation (Getaway Mem-

ber), Word Formation (Willis Ranch Member), Bell Canyon Formation (McCombs Member).

LOCALITIES.—Road Canyon: USNM 720d. Getaway: AMNH 497, 512; USNM 728. Willis Ranch: USNM 706, 724u. McCombs: AMNH 409.

DIAGNOSIS.—Large, misshapen shells with huge ears and interior suggesting *Paucispinifera*.

TYPES.—Holotype: USNM 149449s. Figured paratypes: USNM 149449b, c, p-r, t, u; 154101. Measured paratypes: USNM 149449a-f. Unfigured paratypes: USNM 149449a, d-o.

COMPARISON.—No other species of this genus is now known to which this one may be compared. Resemblance to *Institella* is suggested, but that is a frilled form with a deep sulcus. The same is true of *Craspedona newelli*, new species, which has a frilled anterior and a tendency toward a tubular anterior.

Family LINOPRODUCTIDAE Stehli, 1954

Costellate and rugose Productacea, with rows of fine spines near hinge; sessile, posteriorly trilobate cardinal process but anteriorly with groove in shaft, body cavity small; adductors dendritic.

Subfamily LINOPRODUCTINAE Stehli, 1954

Linoproductidae with wide hinge and long trail.

Genera in West Texas: *Linoproductus* Chao, 1927; *Canocrinella* Fredericks, 1928; *Liraria*, new genus; *Undellaria*, new genus; *Grandaurispina* Muir-Wood and Cooper, 1960; *Holotricharina*, new genus; *Yakovlevia* Fredericks, 1925a; and *Siphonosia*, new genus.

*Linoproductus* is a rare genus in the Glass Mountains and is still rarer in the Guadalupe Mountains. The genus is best developed in the Pennsylvanian and Wolfcampian but tapers off in the Leonardian and above. *Canocrinella* is rare and may be expected in any of the formations. *Liraria* and *Undellaria* are extremely rare and aberrant linoproductids known only from the Sierra Diablo. *Grandaurispina*, capillate and multispinose, appears related to *Canocrinella*. It is very rare in the Cathedral Mountain Formation but becomes abundant in the Willis Ranch Member of the Word Formation. In the Guadalupe Mountains it occurs in the Cherry Canyon and Delaware Mountain formations. *Holotricharina* is rare and confined to Leonardian

rocks in the Glass Mountains. *Yakovlevia* (= *Muirwoodia*) in the Glass Mountains appears first in the Road Canyon Formation, is rare in the China Tank Member of the Word Formation, but becomes abundant in the Willis Ranch Member. It is rare again in the Appel Ranch Member. In the Guadalupe Mountains it is extremely rare in the Cherry Canyon and Delaware Mountain formations. *Siphonostia* is a development paralleling the bizarre *Proboscidella* of the Mississippian; it occurs only in the Cathedral Mountain Formation.

### Genus *Linoproductus* Chao, 1927

*Linoproductus* Chao, 1927:25, 128; 1928:63.—Muir-Wood and Cooper, 1960:296.—Williams et al., 1965:H500.  
*Cora* Fredericks, 1928:781, 790.

This genus has been well described and abundantly discussed and can be regarded as one of the better known productid brachiopods. We see no reason to repeat the well-known details. Unfortunately *Linoproductus* is a rare fossil in the Glass Mountains and very few good specimens have been recovered from the residues. It is more common in the Early Permian than in the formations above Wolfcampian rocks. Of considerable interest is the information obtained by Grant (1963), on the living habits of *L. angustus* R. E. King which indicates that this large brachiopod was attached throughout most, perhaps all, of its life. This information was derived from infant and adult specimens obtained from acid residues which could not have been obtained by any other manner.

### *Linoproductus angustus* R. E. King

PLATE 431: FIGURES 1-3; PLATE 432: FIGURES 1-27; PLATE 453: FIGURES 25-29

*Linoproductus cora angustus* King (part), 1931:76, pl. 16: figs. 8, 9.

*Linoproductus philocrinus* Stehli, 1954:319, pl. 21: figs. 6-10.

*Linoproductus angustus* King.—Grant, 1963:134, pl. 19.

Large, elongate-rectangular in outline, hinge equal to or slightly wider than midwidth. Sides gently rounded, anterior margin narrowly rounded. Surface costellae numbering about five to seven per 5 mm at anterior. Halteroid spines slender, forming dense row along posterior margin and commonly curving medially. Body spines absent or few.

Pedicle valve unevenly convex in lateral profile, most convex at venter but with umbonal region flattened and trail gently curved to nearly flat; an-

terior profile nearly vertical-sided dome with gently rounded crest. Umbonal region gently swollen but with short, steep, lateral slopes, not strongly protruding posterior to hinge; midregion swollen. Sulcus not noticeably developed. Ears large, deeply corrugated, undulations extending in concentric bands on lateral slopes but dying out medially. Trail long and gently curved. Beak with flattened cicatrix of attachment.

Brachial valve with flatly convex venter but strongly geniculated trail; umbonal region broadly depressed; mid-region anterior to umbo gently swollen to form broad fold; lateral areas moderately concave. Ears well demarcated, concave.

Brachial valve interior with moderately large cardinal process, deeply pitted anteriorly and with buttress plates in older specimens; lateral ridges slender, extending laterally to the ears; adductor field not thickened.

MEASUREMENTS (in mm).—From locality USNM 716p, specimen USNM 149462, and from King 105, YPM 11519b, respectively: length 50.4, 48.0; surface length 75.0, 73.0; hinge width 46.4, 39.1; midwidth 43.0? 34.7; height 20.0, 22.5; brachial valve length, and thickness, unmeasurable.

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation, Skinner Ranch Formation (Decie Ranch, Poplar Tank, and Sullivan Peak members).

LOCALITIES.—Bone Spring: AMNH 625, 629, 631; USNM 728e, 728f, 728h. Decie Ranch: USNM 707a, 714t. Poplar Tank: USNM 707ha. Sullivan Peak: USNM 722-l. Skinner Ranch (base): King 105; USNM 705a, 716p, 720e, 720g. Skinner Ranch (top): AMNH 520; USNM 733r.

DIAGNOSIS.—Large *Linoproductus* with dense row of slender medially curving halteroid spines along posterior margin.

TYPES.—Lectotype: YPM 11519a. Paratype: YPM 11519b. Figured hypotypes: T 10057; USNM 140201, 140202, 140203, 140209, 140210, 140214, 140222, 149460, 149462, 152890a-f, 153928. Figured and measured paratype: YPM 11519b. Measured hypotype: USNM 149462.

COMPARISON.—In size this species most resembles *L. semisulcatus*, new species, but differs in having a different arrangement of the halteroid spines along the posterior margin and in not possessing a sulcus. It is quite unlike *L. magnispinus* Dunbar and Condra which has a fair supply of large halteroid spines on the body, especially on the trail slope.



In proposing *L. cora angustus*, King (1931) illustrated two specimens, one belonging to the University of Texas (T10057) and two to Yale University. In the legend to his plate 16 the specimen (YPM 11519a) illustrated by figure 9 is called a cotype but the discussion of the species under the heading of "Distribution" locality 105, from which the specimen under consideration comes, bears the expression "type" after it. This implies that this place is the type locality for the subspecies, and implies that King intended for the specimen illustrated in figure 9 to be the type, although he did not make a specific statement to this effect. Inasmuch as this specimen, although not complete, is nevertheless the better-preserved one, we select it as type. It shows clearly the dense row of spines coming out of the posterior margin, one of the chief features of this species, one so clearly shown in the pedicle valve fragments illustrated by Stehli (1954). Add to these anatomical facts the occurrence of King's "cotypes" and Stehli's specimens at the same horizon, it seems inescapable that the two lots represent the same species.

Stehli (1954:320) belived that the species *L. philocrinus* was attached throughout life. This view is supported by Grant (1963) for several reasons. *Linoproductus angustus* King attached itself by its cardinal spines to a cylindrical object such as a crinoid column, bryozoan, or productoid spine, and there remained suspended throughout its life. Attachment spines grew in pairs, one on each side, beginning first as indentations in the mantle at the posterolateral corners, then as tubes filled by mantle which extended toward the object of attachment. Spines are absent from other parts of the shell. The spat attached parallel to the object of attachment, but anterior growth produced near perpendicularity in mature adults. Apparently some shells lived with the pedicle valve uppermost, others with the pedicle valve down. The tip of the beak of the pedicle valve was the point of original attachment of the shell. It was thin and concave in juveniles, but thickened in adults to form a strong cicatrix that bore against the object of attachment.

### *Linoproductus delicatus*, new species

PLATE 433: FIGURES 24-26

Small, subquadrate in outline with large, deeply grooved ears but small, slender, halteroid spines on

ears and posterior margins. Ears deeply grooved by concentric undulations. Costellae numbering 11 per 5 mm at front margin. Body spines scattered, slender, and delicate.

Pedicle valve fairly strongly convex in lateral profile, median half most strongly curved. Anterior profile steep-sided dome with broadly and gently curved crown. Umbonal region and part of venter visible from dorsal side. Umbonal region broad and swollen, merging into swollen median region. No sulcus visible.

Brachial valve unknown.

MEASUREMENTS (in mm).—From locality USNM 702, specimen 149467a (holotype): length 25.7, surface length 49.0, hinge width 27.0\*, midwidth 27.0, height 13.0?

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITIES.—AMNH 500B; USNM 702, 702-low, 703bs.

DIAGNOSIS.—Small, subquadrate *Linoproductus* with deeply wrinkled ears and small slender halteroid spines.

TYPES.—Holotype: USNM 149467a.

COMPARISONS.—This species is most like *L. undatus*, new species, from the fossil bed of P. B. King (= Taylor Ranch Member) but differs slightly in proportions, having a more swollen and more laterally expanded umbonal region. The ear is deeply grooved, as in *L. undatus*, but the grooves are not so deep and the ridges not so elevated. Another major difference is in the posterior halteroid spines which in *L. delicatus* are slender and directed irregularly, whereas in *L. undatus* these spines are thick and directed parallel to the shell length.

DISCUSSION.—This is a rare species, only 8 specimens having been obtained from all the intensive collecting in the Cathedral Mountain Formation.

### *Linoproductus meniscus* Dunbar and Condra

*Linoproductus meniscus* Dunbar and Condra, 1932:255, pl. 30: figs. 4, 5.

This is a large quadrate *Linoproductus* easily recognized because of its size. The half-measure of a brachial valve from the Gray Limestone Member of P. B. King is 46 mm indicating a specimen about 92 mm wide. Another specimen from the *Uddenites*-bearing Shale Member is 65 mm long. The young are less readily identified but are transversely

oval with softly rounded contours. The species is rare and the few specimens collected are poorly preserved or somewhat crushed.

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member), Neal Ranch Formation (base of Gray Limestone Member of P. B. King).

LOCALITIES.—Gaptank: USNM 701y. *Uddenites*: USNM 701v, 721–l. Neal Ranch: 721k.

DISCUSSION.—Until first-rate material of this species can be found, it will not be possible to be sure of its relationship to *Linoproductus inornatus* R. H. King which occupies approximately the same stratigraphic interval in north-central Texas. The Finis and Wayland shales, members of the Graham Formation, produce *Linoproductus* of enormous proportions; Dunbar and Condra's type specimens of *L. meniscus* are from about the same level.

### *Linoproductus nasutus* R. E. King

PLATE 433: FIGURES 19–23

*Linoproductus nasutus* King, 1931:76, pl. 17: figs. 8, 9.

Elongate-oval outline, hinge extended into definite ears and forming widest part of shell; sides rounded but extending obliquely medially; anterior margin nasute; surface costellate, costellae numbering about 10 per 5 mm at front margin.

Pedicle valve unevenly convex, anterior half moderately convex in lateral profile but posterior half strongly curved; anterior profile broadly domed with short, nearly vertical, lateral slopes; umbonal region swollen, swelling continuing to great inflated venter; median and anterior regions moderately swollen and with precipitous slopes to posterolateral extremities; region just anterior to umbo gently and broadly sulcate, sulcus disappearing anteriorly where median part of anterior quarter folded narrowly to form nasute margin; umbo of ventral valve elongated and swollen to overhang hinge.

Brachial valve in available specimens obscured, little in view indicating concave valve as usual in genus.

MEASUREMENTS (in mm).—From King locality 246, specimen YPM 11523: length 30.3, brachial valve length 21.8, surface length 55.0, height at mid-width 15.0?, hinge width 28.8+, thickness (?).

STRATIGRAPHIC OCCURRENCE.—Word Formation (Appel Ranch Member).

LOCALITIES.—R. E. King 246, 247; USNM 731z.

DIAGNOSIS.—Small *Linoproductus* with strongly nasute anterior margin in the adult.

TYPES.—Holotype: YPM 11523. Figured paratype: T 10096.

COMPARISON.—Dunbar and Condra (1932) illustrate two nasute species: *Linoproductus carinatus* and *L. oklahomae*. Both of these are large, far larger and differently shaped than *L. nasutus*. In both of them, furthermore, the nasute anterior is continued posteriorly and forms a narrowly pinched fold for half or more the valve length. According to King this species is common in the upper Word Formation at his localities 246 and 247.

### *Linoproductus semisulcatus*, new species

PLATE 431: FIGURES 7–12

Large, longer than wide, longitudinally oval in outline. Hinge about equal to midwidth; ears prominent, acutely pointed; sides gently rounded; anterior margin broadly curved. Surface finely costellate, costellae appearing in several generations, numbering 7 to 9 at midvalve and 8 to 9 in 5 mm at front margin.

Pedicle valve unevenly convex, anterior half gently convex in lateral profile, posterior half strongly convex, venter strongly curved, and umbonal region strongly convex; anterior profile a broad, gently and evenly convex dome with precipitous sides. Umbonal region and venter strongly convex and protruding strongly posterior to hinge (seen in dorsal view). Median region strongly swollen. Sulcus originating on anterior side of venter, broad and shallow, extending for about half valve length, there merging into gentle and even convexity of long trail. Umbonal slopes long and steep. Lateral slopes and ears strongly wrinkled. Posterior margin and ears with narrow tuft of halteroid spines; body spines not observed, probably few and scattered.

Brachial valve unevenly convex in profile, posterior third flatly concave, anterior two-thirds gently convex; angle of geniculation about 55°. Brachial valve forming shallow concavity of unequal depth, umbonal region forming rounded depression, median region forming fairly strong, broadly carinate

fold, areas bounding fold fairly deep. Sides and anterior steep. Ears and venter marked by broad concentric wrinkles. Trail long and gently convex.

Interior of pedicle valve with strongly marked muscle field; brachial valve with stout cardinal process, strongly dendritic adductor field, and strong lateral ridges. Other features not seen.

MEASUREMENTS (in mm).—From locality USNM 715b, specimens 149490a (holotype) and 149490b, respectively: length 42.5, (?); brachial valve length (?), 30.7; surface length 95.0, 61.0; hinge width 40+, (?); midwidth 49.6? 41.4; height 30.7, (?); thickness unmeasurable.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch and Lenox Hills formations.

LOCALITIES.—Neal Ranch: USNM 701c, 701d, 702h, 706x, 712z. Lenox Hills: USNM 715b, 731k, 737u.

DIAGNOSIS.—Large, elongate *Linoproductus* with a broad sulcus at midvalve that does not extend to the anterior margin, but with a tuft of fine spines on the posterior margin and ears.

TYPES.—Holotype: USNM 149490a. Figured paratype: USNM 149490b.

COMPARISONS.—This species is large and elongate, unlike the others described in the Glass Mountains. It is unique in that the sulcus of the pedicle valve is confined to the median part of the valve length. It suggests *Linoproductus platyumbonus* Dunbar and Condra, which has a flattened venter with a shallow sulcus originating on its anterior slope, but not extending to the anterior margin. Dunbar and Condra's species differs from *L. semi-sulcatus* in being wider and anteriorly somewhat nasute. This is an uncommon species in the Glass Mountains and good specimens are difficult to obtain.

*Linoproductus undatus*, new species

PLATE 433: FIGURES 27-43

Small, quadrate in outline, hinge equal to or slightly greater than midwidth; sides straight to slightly rounded; anterior margin nearly straight to gently rounded. Ears large, subrectangular, deeply furrowed in longitudinal direction. Surface costellate, costellae broad and separated by interspaces narrower than costellae; about 10-12 costellae in 5 mm at front margin. Spines few; posterior margin with 4 or 5 large, long, halteroid spines on

each side of beak; curving to form ring, body spines few, scattered most on anterior and anterolateral parts, usually long and stout and leaving large rounded bases.

Pedicle valve unevenly convex in lateral profile, anterior half gently convex but posterior half more strongly curved; anterior profile high dome with precipitous sides; umbonal region swollen and narrowly convex, widening into swollen venter; median region and trail swollen; sulcus, when clearly visible, originating on venter, broad and shallow, usually obscure; slopes to cardinal extremities steep; ears marked by two deep longitudinal grooves separated by thick ridges continuous with concentric undulations diminishing on flanks of trail.

Brachial valve moderately concave, umbo deeply depressed; venter moderately concave, most concave near line of geniculation; ears demarcated by narrow oblique fold crossed by one or two longitudinal ridges corresponding to ear grooves of pedicle valve; ears flattened; angle of geniculation about 85°; fold inconspicuous or not developed.

Pedicle valve interior not known. Brachial valve interior with small cardinal process having large median lobe, narrow lateral lobes, and deep anterior pit or antron; lateral ridges strong.

MEASUREMENTS (in mm).—Brachial valve length, and thickness, unmeasurable.

	length	surface length	hinge width	mid-width	height
USNM 702m					
159455a	21.7	39.0	24.0*	21.4	11.7
USNM 702e					
149453a	21.6	38.0	20.8	22.2	11.3
USNM 702f					
149454a	23.4	40.0	29.2	24.8	12.3
149454d	21.2	35.0	22.0*	24.2	14.5
(holotype)					

STRATIGRAPHIC OCCURRENCE.—Hess Formation (Fossil bed of P. B. King = Taylor Ranch Member).

LOCALITIES.—USNM 702d, 702e, 702f, 702m, 716n, 716o, 722p.

DIAGNOSIS.—Small, quadrate *Linoproductus* with a row of stout halteroid spines along the posterior margin.

TYPES.—Holotype: USNM 149454d. Figured paratypes: USNM 149454a-c, 149455e. Measured paratypes: USNM 149453a, 149454a, 149455a. Unfigured paratypes: USNM 149453a, 149455a-d.

COMPARISONS.—This species is most like *L. delicatus*, new species, being only slightly smaller but differing in the row of stout halteroid spines on both sides of the beak. *Linoproductus undatus* differs from *L. magnispinus* Dunbar and Condra in size, shorter body spines, finer ornament, and in having the row of stout halteroid spines along the posterior diverging laterally rather than extending at a right angle to the direction of the hinge.

DISCUSSION.—The beak of this species is deformed by a small cicatrix of attachment and the remnants of an attachment ring. The spines all curve medially, a tendency started initially by the formation of the ring. The farthest out, or younger spines, all curve inward and in one specimen they curve anteriorly to run along the umbo. This emphasizes the ringlike arrangement. It is unclear whether or not this species was attached by its spines during life. Permanently attached forms usually have an interarea or palintrope, but this is not developed in *Linoproductus*, a condition which suggests that it lived free in adult life; thus, it is probable that *L. undatus* lived free throughout its adult existence.

### *Linoproductus* species 1

PLATE 431: FIGURES 4–6

Two specimens from the *Uddenites*-bearing Shale Member suggest an undescribed nasute form. The outline is subtriangular but the hinge is slightly narrower than the midwidth; the sides are broadly rounded but the anterior narrowly rounded; the lateral profile is moderately and evenly convex, the anterior profile is a high tapering dome with steeply sloping sides. Umbonal and medial regions are strongly swollen and the anteromedian third is marked by a poorly defined carina. The ears are rounded and marked by strong wrinkles. The surface has eight or nine costellae in 5 mm at the front margin.

The brachial valve is gently concave with the anterior narrowly deflected. The ears are strongly wrinkled as is most of the visceral region. The cardinal process is small and two-pronged when viewed from the ventral side.

Figured specimen: USNM 152772a.

MEASUREMENTS (in mm).—From locality USNM 701q, pedicle valve 152772a and brachial valve 152772b, respectively: length 41.8, 29.0; surface length 69.0, (?); hinge width 45.2, 45.0\*; midwidth

45.5, 38.4; height 16.7, (?); thickness unmeasurable.

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member).

LOCALITY.—USNM 701q.

DIAGNOSIS.—Somewhat bulbous, subtriangular *Linoproductus* with nasute anterior.

COMPARISON.—This species is larger than and completely unlike *L. nasutus* R. E. King but suggests *L. oklahomae* and *L. carinatus*, both of Dunbar and Condra. It is smaller than either of these, is medially more swollen, does not have an anterior notch, and the carination is not so strong.

### *Linoproductus* species indeterminate

A fair number of specimens from various places could not be placed in known species. Several species not defined or mentioned above are present but will have to await more adequate material for description.

The localities are: AMNH 492; USNM 700e, 700f, 700g, 701, 701a, 701a<sup>3</sup>, 701c, 701d, 701e, 701f, 701p, 701r, 701t, 701x, 702q, 703–1, 704r, 705h, 705n, 705v, 707b, 708b, 713j, 715f, 715z, 721u, 731–1.

### Genus *Cancrinella* Fredericks, 1928

*Cancrinella* Fredericks, 1928:784, 791.—Sarycheva, 1937:78, 110.—Muir-Wood and Cooper, 1960:301.—Williams et al., 1965:H500.

This genus has had a struggle for existence; some writers have regarded it as a synonym of *Linoproductus*, others have favored a subgeneric status for the name. A few, however, have maintained an independent generic status for it. *Cancrinella*, as its interior clearly reveals, is a linoproductid but its exterior is definitely not the same as that of *Linoproductus*. The spine arrangement along the hinge and on the body is different. In *Cancrinella* the posterior margin is spiny and generally a tuft of long halteroid spines is developed on the ears. In *Linoproductus* the halteroid spines along the posterior margin generally form a single row. Body spines of *Linoproductus* are generally large, few and scattered, appearing at a high angle to the shell surface and functioned essentially as halteroid spines. In *Cancrinella* body spines are numerous and arise at a low angle to the shell surface. The appearance of the two genera, when adorned by



their full complement of spines, is entirely different in appearance.

TYPE-SPECIES.—*Productus cancrini* Verneuil (1845: 273, pl. 16: figs. 8a–c; pl. 18: figs. 7).

DISCUSSION.—This genus is one of the rarest in the Glass Mountains. The shells are generally thin and fragile and many may be lost in the etching process. The few recovered give an interesting picture of the genus, some specimens being fully adorned with their spines.

### *Cancrinella distorta*, new species

PLATE 428: FIGURES 1–11, 41–43

*Linoproductus (Cancrinella) phosphaticus* R. E. King (not Girty), 1931:77, pl. 17: figs. 6, 7.

Medium size for genus; elongate oval in outline, hinge forming widest part. Sides gently curved; anterior narrowly rounded. Surface marked by concentric wrinkles and costellae; wrinkles strongest on ears and lateral slopes but more subdued and irregular on venter and trail. Costellae rounded, with narrow interspaces, numbering about 8 per 5 mm at front margin. Halteroid spines slender in narrow tufts on ears. Body spines arising from end of elongate swollen bases and extending at low angle to surface. Brachial valve costellate, wrinkled, and having sporadic swollen costellae but no spines.

Pedicle valve in lateral profile most strongly curved in posterior third, trail long and moderately convex. Anterior profile narrowly rounded, steep-sided dome. Beak small and overhanging brachial valve beak; umbo narrowly swollen but expanding into swollen venter; umbonal region protruding moderately posterior to hinge when viewed from dorsal side. Ears moderately large, approximating right angle. No sulcus.

Brachial valve deeply concave, maximum depth near midvalve; sides and anterior steep; ears well demarcated. Sides and ears marked by strong concentric wrinkles.

Brachial valve interior with low but moderately large cardinal process and long slender brevisseptum reaching to about midvalve.

MEASUREMENTS (in mm).—From King locality 247, specimen YPM 10775, and from USNM locality 715i, holotype USNM 152773, respectively: length 27.1, 27.6; brachial valve length (?), 21.0;

surface length 50.0, 50.0?; hinge width 18.6\*, 23.0?; midwidth 20.7, 19.3; height 14.7, 15.9; thickness (?), 5.2.

STRATIGRAPHIC OCCURRENCE.—Word Formation (Appel Ranch Member).

LOCALITIES.—R. E. King 247; USNM 715i, 719z, 731z.

DIAGNOSIS.—Elongate, nearly parallel-sided *Cancrinella* with elongated spine bases.

TYPES.—Holotype: USNM 152773. Figured paratypes: USNM 153851a, b; YPM 10775.

COMPARISONS.—King identified this species as *Cancrinella phosphatica* (Girty) but comparison with the type specimens of Girty's species indicate many differences. *Cancrinella phosphatica* is much larger, has more spreading flanks, and a more flaring anterior margin. The umbo of *C. distorta* is narrower than that of Girty's species and the ears more prominent. The spine bases of *C. phosphatica* are elongated like those of *C. distorta*, but they appear to be more scattered on the larger species.

The more swollen and narrower umbonal region separate *C. distorta* from *C. subquadrata*, new species; another point of difference is in the nearly equal length and width of the latter. The more flattened umbonal region and the smaller, less elongated spine bases separate *C. planumbona*, new species, from *C. distorta*; the ears are less extended on the lower Word form, and the visceral disc region is somewhat more wrinkled than in *C. distorta*.

This species, like all others of this genus, is rare in the Glass Mountains.

### *Cancrinella expansa*, new species

PLATE 429: FIGURES 8–15

Large, quadrate outline, slightly wider than long, with nearly straight sides and well-rounded anterior. Strongly convex in lateral profile but with umbo protruding only slightly posterior to hinge. Ears small and forming nearly right angle. Surface marked by distant strong wrinkles and costellae; costellae numbering 8 or 9 per 5 mm near midvalve. Spine bases elongated, widely scattered. Spines thin and delicate, forming tuft on each ear and narrow tuft along posterior margin. Sulcus absent. Brachial valve unknown.

MEASUREMENTS (in mm).—From locality USNM 706b, specimen 153856b (holotype): length 25.0, midwidth 27.8, hinge width 27.3, height 15.0.



STRATIGRAPHIC OCCURRENCE.—Word Formation (lens between the Willis Ranch and Appel Ranch members).

LOCALITY.—USNM 706b.

DIAGNOSIS.—Wide, strongly convex *Cancrinella* with low umbo.

TYPES.—Holotype: USNM 153856b. Figured paratype: USNM 153856a.

COMPARISON AND DISCUSSION.—This species is like *C. planumbona*, new species, but is larger, wider and squarer, less wrinkled, and has a thicker spine brush. It is also similar to *C. subquadrata*, new species, but is less spiny and has smaller ears, although the exterior appears to be otherwise similar. We have no complete adult pedicle valves of *C. subquadrata* to use for comparison.

### *Cancrinella fragosa*, new species

PLATE 428: FIGURES 12–18

Subquadrate to elongate oval in outline, with gently curved sides but narrowly rounded anterior margin. Hinge less than or about equal to

midwidth; surface costellate and undulated, costellae broad and low, with narrow interspaces, numbering 9 to 11 per 5 mm at front margin. Undulations numerous, strong on ears and lateral slopes, more distant and less prominent on venter and trail. Ears with fine spines as indicated by bases; body with scattered delicate spines arising from elongate bases.

Pedicle valve unevenly convex in lateral profile, greatest convexity in posterior third, anterior two-thirds gently convex; anterior profile a narrowly rounded, steep-sided dome. Umbonal region moderately inflated and protruding moderately posterior to hinge. Median region inflated. Ears small, strongly wrinkled, and approximating a right angle. No sulcus.

Brachial valve quadrate in outline, fairly deeply convex, with steeply sloping sides and anterior; deepest near midvalve; umbonal region depressed; surface undulations less deep and strong than those of opposite valve; scattered small pits corresponding to spine bases of pedicle valve.

Interior of both valves unknown.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 712p							
152774a	17.0	?	27.0	15.0?	14.9	9.4	?
152774b	21.0	?	31.5	13.8*	16.8	11.4	?
(holotype)							
152774c	15.6	?	25.0	13.0	15.5	7.6	?
152774d	17.5	?	28.0	14.0*	14.6	8.8	?
152774e	14.2	?	22.5	13.1	14.5	8.0	?
152774f	17.5	?	26.5	12.8*	16.6	7.6	?
152774g	11.0	?	16.0	10.0	12.6	5.5	?
152774h	9.7	?	12.5	8.2	9.5	2.8	?
152774i	7.0	?	8.5	6.8	6.8	2.1	?
152774j	?	10.6	14.0	12.4	13.7	?	?
152774k	16.1	?	26.0	?	13.6*	9.2?	3.1?
152774l	11.4	?	16.0	?	11.8	4.5	3.2
152774m	?	11.8	16.0	12.6*	14.9	?	?
152774n	18.7	14.7	32.0	9.1?	12.0	9.9	3.1

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (base and Sullivan Peak Member).

LOCALITIES.—Skinner Ranch (base): USNM 712p. Sullivan Peak: USNM 710r.

DIAGNOSIS.—Small, strongly convex, umbonate *Cancrinella* with most of the body strongly wrinkled.

TYPES.—Holotype: USNM 152774b. Figured paratypes: USNM 152774a, o. Measured paratypes: USNM 152774a, c–n. Unfigured paratypes: USNM 152774c–n.

COMPARISON.—No specimens of this species are silicified, making comparison with silicified forms difficult. Actually no adult *Cancrinella* now known

from the Glass Mountains is quite like this one. The specimens are generally small and appear to be elongate, but that impression is deceptive because the length and width are nearly equal, the species is considerably smaller than *C. distorta*, new species, which suggests it in profile and outline, but *C. distorta* is not so strongly wrinkled on the body, has longer spine bases, and is more umbonate than *C. fragosa*, new species.

***Cancrinella parva*, new species**

PLATE 428: FIGURES 19–40

Small, quadrate in outline, with rounded sides and somewhat narrowly rounded anterior margin. Hinge width about equal to midwidth; ears small and inconspicuous. Surface marked by numerous closely spaced concentric undulations strongest on lateral slopes but well marked on venter and trail, covering entire surface. Costellae rounded, numbering 4 per millimeter at front margin. Halteroid spines long and extending mostly posterolaterally,

but some directed anterolaterally or ventrally; body spines long and curved, arising from short, narrow bases at low angle and extending almost parallel to valve surface. Brachial valve with similar markings to those of pedicle valve, undulations strong and regular.

Pedicle valve with fairly regularly curved lateral profile, moderately convex but with umbonal region forming most convex part. Anterior profile, somewhat narrow dome with steeply sloping sides. Umbonal region gently convex and slightly protruding posterior to hinge; median region and sides strongly swollen.

Brachial valve forming shallow concavity with sides and anterior sloping moderately toward mid-region. Ears poorly defined.

Pedicle valve interior with no visible markings. Brachial valve interior with short brevisseptum and large bilobed cardinal process, lobes separated or confluent, when confluent having anterior shallow depression. Anterior trail slope with numerous strong endospines.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 701d							
152775a	8.0	7.1?	11.5?	7.3	8.2	3.8	?
152775b	7.3	6.3	11.5	7.8	7.6	3.5	2.3
USNM 701							
152776a	7.6	6.7?	12.0	6.9	7.9	3.8	?
152776b	?	7.2	?	5.3	8.0	?	?
152776c	9.5	8.5?	13.0	6.8	8.8	5.9	3.1
USNM 701a <sup>1</sup>							
153854	9.8	9.1	?	8.9	9.9	6.6	?
(holotype)							

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (beds 2–14) of P. B. King, Skinner Ranch Formation (Poplar Tank Member).

LOCALITIES.—Neal Ranch: USNM 701, 701a<sup>1</sup>, 701c, 701d. Poplar Tank: USNM 741k.

DIAGNOSIS.—Small *Cancrinella* with length and midwidth about equal.

COMPARISON.—This species strongly resembles *Cancrinella boonensis* (Swallow), common in parts of the Pennsylvanian System. The Wolfcampian species, however, is different in outline because the Pennsylvanian species is considerably wider than long. This is the only important difference noted

between the two species. The length of the body spines has not been recorded for the Pennsylvanian species.

TYPES.—Holotype: USNM 153854. Figured paratypes: USNM 152775a–c, 153852, 153853a–d. Measured paratypes: USNM 152775a, b; 152776a–c. Unfigured paratypes: USNM 152776a–c.

***Cancrinella planumbona*, new species**

PLATE 429: FIGURES 1–7

Medium-sized for genus, longitudinally rectangular in outline, sides gently curved and nearly par-

allel; anterior margin narrowly rounded. Hinge narrower than midwidth. Surface marked by fairly regular concentric undulations, strongest on ears and lateral slopes but nearly as strong elsewhere. Costellae numbering about 9 per 5 mm at front margin. Spine bases small, numerous and well scattered over surface. Halteroid spines slender, concentrated in narrow band along posterior margin.

Pedicle valve fairly evenly convex in lateral profile with posterior third somewhat flattened. Anterior profile broad, steep-sided dome. Umbonal region only slightly swollen and barely visible posterior to hinge when seen from dorsal side. Median region swollen; trail long and gently convex. Ears small, inconspicuous.

No complete brachial valve known.

Interior details of pedicle valve too lightly impressed to be analyzed. Brachial valve with small, low cardinal process, delicate lateral ridges, and slender brevisseptum.

MEASUREMENTS (in mm).—From locality USNM 706c, specimen 152779a (holotype): length 24.0, brachial valve length 22.0?, surface length 34.0, hinge width 19.0, midwidth 22.3, height 11.9, thickness unmeasurable.

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank Member).

LOCALITY.—USNM 706c.

DIAGNOSIS.—Medium-sized *Cancrinella* with flattened umbonal region, numerous body spines, and well-wrinkled shell.

TYPES.—Holotype: USNM 152779a. Figured paratypes: USNM 152779b.

COMPARISONS.—This species resembles *C. distorta*, new species, but differs in having a much lower umbo, that feature being scarcely visible posterior to the hinge when viewed from the dorsal side. It also differs in having less prominent ears, and more regular undulations over the shell body. *Cancrinella planumbona* differs from *C. subquadrata*, new species, in having a greater length than midwidth, much lower umbonal region, and more body spines which arise at a higher angle to the shell surface than those of the higher Word species. This species is excessively rare, only a few specimens having been obtained from the hundreds of pounds of rock dissolved from USNM 706c.

## *Cancrinella sparsispinosa*, new species

PLATE 430: FIGURES 15–47

*Cancrinella altissima* Stehli (not R. H. King), 1954:321, pl. 22: figs. 1–5.

Medium for genus, pedicle valve swollen, width greater than length; hinge of pedicle valve generally slightly narrower than midwidth; sides and anterior margin broadly rounded. Surface costellae numbering 3 per mm at front of largest specimen. Undulations concentric, strong, wavy, discontinuous, and prominent on all parts. Spines fairly numerous on posterior margin and ears; body spines attaining length of 7 mm, about 3 mm apart, arranged in crude concentric rows, and given off at angle of 60° (or more).

Pedicle valve strongly convex in lateral profile, maximum convexity in posterior third; anterior profile an evenly curved, rounded dome narrowing slightly upward and with very steep sides. Umbonal and median regions tumid. Ears prominent, not extended laterally, but strongly wrinkled. Flanks swollen.

Brachial valve transversely elliptical with ears and lateral regions strongly undulated concentrically; median region forming deepest part of valve and sides sloping steeply inward. Ears prominent, deflected, somewhat flattened, and prominent.

Pedicle valve interior without well-defined details because of delicacy of shell. Brachial valve interior with small, short, and sessile cardinal process having well-developed lateral ridges; brevisseptum short and delicate, not reaching midvalve; muscle scars not thickened; trail slope with long, thin, very delicate endospines.

MEASUREMENTS (in mm).—Thickness unmeasurable.

		<i>brach- ial valve length</i>	<i>sur- face length</i>	<i>hinge width</i>	<i>mid- width</i>	<i>height</i>
USNM 728f						
152780a (holotype)	18.8	?	25.0	17.0*	20.6	8.0?
152780b	17.6	?	25.0	16.6	18.9	9.0?
152780c	18.8	?	30.0	18.3	19.8	11.0?
152780d	21.4	?	32.0	24.4*	26.8*	11.0?
152780e	15.2	?	23.0	13.5	15.6	8.5
152780f	?	16.2	?	26.6*	25.3	?
152780g	?	18.2	?	27.7	24.4*	?

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (base). Bone Spring Formation.

LOCALITIES.—Skinner Ranch (base): USNM 720e. Bone Spring: AMNH 629; USNM 728e, 728f, 728h.

DIAGNOSIS.—Roundly elliptical *Canocrinella* of medium size with sparsely placed long body spines.

TYPES.—Holotype: USNM 152780a. Figured paratypes: USNM 152780b, g-m. Measured paratypes: USNM 152780b-g. Unfigured paratypes: USNM 152780c-f.

COMPARISON.—*Canocrinella altissima*, to which Stehli referred this species, was described by R. H. King as "an extremely high, narrow, elongate form." It is also a large species, larger than any of the specimens taken from the Bone Spring Formation. *Canocrinella sparsispinosa* thus differs importantly from King's species by its transverse outline.

DISCUSSION.—The shells of *Canocrinella sparsispinosa* are so thin and fragile that it is nearly impossible to obtain perfect specimens. The measured specimens are nearly all imperfect and necessitate the making of half-measures for some of the dimensions, especially the hinge and midwidths. The shells are so thin that no details of the pedicle valve interior have been obtained, although that valve is fairly common. The interior of the brachial valve has more detail, and good specimens were obtained. The cardinal process is usually very small and is usually rotated to a fairly high angle with the hinge. It is typically linoproductid with a deep longitudinal depression, making the ventral aspect often bilobed. Posteriorly it is trilobed, with a wide median lobe in the myophore. The delicacy and small size of the brevisseptum are striking. Another feature not usually seen is the abundance of delicate, needle-pointed endospines that cover the trail slope.

### *Canocrinella subquadrata*, new species

PLATE 429: FIGURES 16-40

Large, subquadrate, width slightly greater than length; sides gently rounded; anterior margin broadly rounded; hinge about equal to midwidth; ears small, approximating right angle. Surface costellate and wrinkled, wrinkling strongest on ears and lower part of lateral slopes, gentle on venter and trail, nowhere strong except on the ears; costellae broad and flatly rounded, with narrow

interspaces, numbering about 8 per 5 mm near front margin. Halteroid spines, slender and concentrated in tuft on each ear; body spines fairly long, delicate, oblique to surface at low angle and with short, swollen bases. Brachial valve with spines near anterior margin.

Pedicle valve moderately and fairly evenly convex in lateral profile, only abruptly greater curvature of umbonal region affecting convexity; anterior profile a broad but steep-sided dome. Umbonal region broadly but gently swollen and slightly protruding posterior to hinge in dorsal view. Median region strongly swollen. Trail gently swollen.

Brachial valve with moderate concavity and most concave in posterior third; sides and anterior margins moderately steep; ears well demarcated and strongly wrinkled; posterior margin strongly wrinkled.

Pedicle valve so thin and muscle scars so lightly impressed as to be indistinguishable. Brachial valve interior with small and delicate cardinal process; lateral ridge moderately thickened; brevisseptum delicate, not reaching midvalve; muscle scars not distinguishable.

MEASUREMENTS (in mm).—From localities USNM 706e, specimen 152777 (holotype), and 735c, specimen 153858a, respectively: length 18.2, (?); brachial valve length (?), 23.7; hinge width 17.2\*, 27.2; midwidth 20.6; 24.0; height 7.6, (?); thickness unmeasurable.

STRATIGRAPHIC OCCURRENCE.—Word Formation (Willis Ranch and Appel Ranch members and lens between them).

LOCALITIES.—Willis Ranch: AMNH 505; USNM 706, 706e, 735c. Appel Ranch: 715i, 719z. Lens: 706b.

DIAGNOSIS.—Subrectangular *Canocrinella* with moderately inflated umbonal region.

TYPES.—Holotype: USNM 152777. Figured paratypes: USNM 153857a-e, 153858a. Measured paratype: USNM 153858a.

COMPARISON.—This species appears to be intermediate between *C. planumbona* and *C. distorta*, both new. It differs from the former in having greater width than length and from the latter in its outlines and proportions. It differs from both in having the umbonal region more swollen than in *C. planumbona* but much less swollen than in *C. distorta*.

*Cancrinella* species 1

PLATE 430: FIGURES 4-6

Medium size for genus, wider than long, somewhat elliptical in outline; sides strongly rounded; anterior margin broadly rounded. Hinge narrower than midwidth; ears small, obtuse. Surface marked by fine concentric undulations, best shown in ears and sides, but strong on trail, less so on venter. Halteroid spines in tuft of slender unruly spines on each ear; body spines short, delicate, arising from small elongate bases.

Pedicle valve strongly convex in lateral profile, fairly evenly convex except for strong curvature of umbonal region. Anterior profile a broad, narrowly rounded dome with steeply sloping sides. Medial region strongly swollen. Umbonal region slightly elevated posterior to hinge when seen in dorsal view.

Brachial valve deeply convex with most convexity slightly posterior to center. Ears not well demarcated, strongly wrinkled. Sides and anterior sloping moderately steeply.

Interior not known.

Figured specimens: USNM 152781, 153855a-c.

MEASUREMENTS (in mm).—From locality USNM 702b, specimen 152781: Length 13.2?, brachial valve length 11.8, surface length 21.5, hinge width 16.5, midwidth 19.4+, height 7.0, thickness 2.7.

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITIES.—USNM 702b, 703bs.

DIAGNOSIS.—Transverse *Cancrinella* with delicate body spines and fine concentric undulations.

DISCUSSION.—This species is best represented by a single adult specimen which, unfortunately, is not complete along the anterior margin and one side. Several half-grown pedicle valves confirm the form of the species. Young specimens up to 7 mm in length preserve the initial attachment ring, and the two succeeding sets of posterior halteroid spines also contribute to the ring. They extend medially and wrap around the initial ring to reinforce the hold of the shell on its support. The attachment cicatrix on the umbo is minute in all the specimens with rings observed.

*Cancrinella* species unidentifiable

Specimens of *Cancrinella* too poor or too few to identify or describe were found at the following

localities: AMNH 512, 600; USNM 701e, 701q, 701v, 702b (USNM 153855a-c, see pl. 428: figs. 44-47), 705m, 707a, 712o, 719q, 727e (USNM 153860; see pl. 430; figs. 7-10), 728d, 732, 732a, 746 (USNM 153859a, b, see pl. 430, figs. 1-3). One of these lots (USNM 732a) has the youngest *Cancrinella* found from West Texas during this study, a specimen from the Hegler Member of the Bell Canyon Formation.

*Liraria*, new genus[Latin *lira* (ridge)]

Moderately large, wider than long, somewhat rectangular to semicircular or semielliptical in outline. Hinge widest part. Concavo-convex with narrow or thin visceral cavity; no marked trail. Brachial valve fairly deeply concave. Ears variable. Both valves costellate; only brachial valve spinose. Spines all of halteroid type, slender; a row of oblique spines along posterior margin from umbonal slope to each ear extremity, each row drifting anteriorly in lateral direction; few and scattered spines on shell body.

Pedicle valve without ginglymus; muscle region large; adductor scars small, located posteromedially in pit; diductor scars large and flabellate, surrounding adductors. Ear baffle not strongly developed; subperipheral rim moderately strong in old shells.

Brachial valve with low, small, sessile cardinal process of linoproductid type; zygidium thin but well developed; cardinal process with short double shaft; posterior platform moderately thickened. Adductor field spread laterally, anterior scars near together, posterior pair widely separated. Brevisseptum almost obsolete, its place being taken by two slightly divergent thick ridges separating anterior adductor scars. No subperipheral rim or diaphragms.

TYPE-SPECIES.—*Liraria lirata*, new species.

DIAGNOSIS.—Short, wide Linoproductidae with nearly obsolete brevisseptum, small cardinal process with zygidium.

COMPARISON.—This genus, in its short and wide subsemicircular outline, most nearly resembles *Megousia* Muir-Wood and Cooper, *Anidanthus* Whitehouse, and (*Globiella* Muir-Wood and Cooper =) *Stepanoviella* Zavadowsky. From *Megousia* it differs in not having the extravagant development of the ears on the brachial valve so distinctive



of that genus. From *Anidanthus* it differs in not having a strongly developed brevisseptum and in not having the strong imbricate ornament of the brachial valve. The exterior of *Liraria* differs from that of *Stepanoviella* in being much wider than long; and although the interiors of the brachial valves are somewhat similar, the latter also having two thick ridges dividing the anterior adductor scars, *Stepanoviella* is distinguished by the absence of a zygidium and the presence of a well-developed brevisseptum.

DISCUSSION.—The pedicle valve of *Liraria*, aside from its outline and shortness, does not depart markedly from the usual characters of the Linoproductidae. The brachial valve, on the other hand, shows some interesting deviation. It possesses a thin but well-marked zygidium which is a continuation of the lateral ridges on each side of the cardinal process. Another departure of note is the presence of the two slightly divergent, strong ridges occupying the median line anterior to the cardinal process and separating the two anterior adductor scars. These ridges lie just anterior to the brevisseptum, which is much aborted. The lateral ridges that extend obliquely laterally from the cardinal process are better developed than is usual.

*Liraria lirata*, new species

PLATE 434: FIGURES 9-30

Medium size for Productacea, wider than long, with hinge varying from narrower than midwidth to considerably wider than midwidth. Cardinal extremities varying from rounded to alate, sides moderately rounded; anterior margin broadly rounded, slightly emarginate. Surface of both valves costellate, costellae fine and crowded, width of costellae slightly greater than interspaces; costellae increasing by implantation in several generations, numbering 2 per mm near anterior margin. Spines few, slender, delicate, forming an oblique row just anterior to posterior margin and running onto ear extremity. Body spines few.

Pedicle valve moderately and evenly convex in lateral profile; anterior profile broadly domed, with fairly long steep slopes. Beak small, low; umbonal region gently convex, with low, short umbonal slopes. Median region moderately swollen. Anterior slope moderately long and steep. Lateral slopes steep. Ears depressed and at bases of long slopes.

Brachial valve fairly deeply concave, greatest concavity and depth slightly posterior to midvalve. Flanks and anterior sloping fairly strongly toward midvalve. Beak region a moderately deeply depressed pit, ears slightly concave and not strongly differentiated from flanks.

Interiors of both valves as described for genus.

MEASUREMENTS (in mm).—Thickness unmeasurable.

		<i>brach- ial valve length</i>	<i>sur- face length</i>	<i>hinge width</i>	<i>mid- width</i>	<i>height</i>
USNM 728e						
152782a	16.8	15.4	23.5	27.3	24.3	7.3
(holotype)						
152782b	19.3	18.0	27.5	23.3	26.0	8.3
152782c	18.0	17.0	26.0	26.5	24.6	7.0
152782d	17.4	16.3	26.0	23.9	24.2	7.3
152782e	16.2	15.2	24.0	26.0?	23.1?	6.6
152782f	16.4	14.8	24.5	25.0	22.7	7.5
152782g	18.2	17.1	26.5	21.5	23.5	8.0
152782h	16.0	14.4	24.0	24.9	22.5	7.3

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation (10 feet above top of Hueco Canyon Formation).

LOCALITIES.—AMNH 625, USNM 728e.

DIAGNOSIS.—*Liraria* with the length 0.7 to 0.8 of the midwidth and 2 costellae per millimeter at the anterior.

TYPES.—Holotype: USNM 152782a. Figured paratypes: 152782b, i-k. Unfigured paratypes: USNM 152782c-h. Measured paratypes: USNM 152782b-h.

COMPARISON.—No other species of this genus is known to which this one may be compared. The larger Word Formation *Megousia* which resemble this shell on the pedicle side are readily distinguished by their prominent ears.

DISCUSSION.—The development of the interior details is not uniform, especially in the pedicle valves. Thickening of the valves does not appear to be wholly due to age because some of the smaller shells have the submarginal thickening better developed than others that are larger. The marginal thickening is seldom a very prominent feature of the pedicle valve interior.

*Undellaria*, new genus

[Latin *unda* (wave)]

Large, subcircular outline, hinge narrower than

midwidth; pedicle valve strongly swollen; brachial valve deeply concave; visceral cavity small or thin; beak small; ears poorly developed, usually obtuse. Valves without radial ornament; undulations prominent in posterolateral regions. Spines halteroid, thin and delicate, numerous, concentrated on umbolateral slopes and ears, less numerous medially but fairly abundant on anterior and anterolateral slopes.

Pedicle valve without ginglymus, with very small muscle area for large shell confined to umbonal region; diductor scars enclosing adductor scars; diductor scars small and flabellate and separated by two low ridges occupying median part of muscle region. Remainder of valve smooth in median region, granulose anteriorly.

Brachial valve with correspondingly small structures. Cardinal process linoproductid, sessile, very small, bilobed on ventral side, lobes separated by deep median depression; myophores narrow. No zygidium. Lateral ridges incipient. Adductor field bilobed anteriorly, anterior adductors attached to small elevated platforms. Brevisseptum short, not reaching midvalve, thin, delicate, rising to crest anteriorly, and with steep descent in the same direction.

TYPE-SPECIES.—*Undellaria magnifica*, new species.

DIAGNOSIS.—Large, noncostellate Linoproductidae with small muscle areas and numerous delicate spines.

COMPARISON.—The undulated noncostellate valves, and numerous delicate spines of this genus are unlike any other of the Linoproductidae.

DISCUSSION.—This genus is distinctive not only in its appearance but also in certain unique characters on the inside. It is subcircular in outline, large, and strongly convex. Spines are unusually delicate and slender for such a large shell and are concentrated along the posterior margin, where many of them project at right angles or are slightly oblique to the hinge margin. Many are also concentrated on the ears, but are not so well developed there. Spines also appear on the umbolateral, lateral, and anterior slopes. In these regions they are somewhat more widely spaced than on the posterior margin. The strongly rounded median region has more distant spines.

One specimen preserves an attachment ring of the young shell at the beak. The umbo shows a

slight grooving produced by the small cylindrical object to which it was at one time attached, probably a productid spine. The first two spines to be formed looped over the attachment object and then fastened themselves to the surface of the umbo, making the shell fast. They then strengthened the attachment by running for some distance along the umbonal surface.

The brachial valve is also notable for the delicacy of its internal structures. The cardinal process is small, sessile, and typically linoproductid. It is bilobed in posterior view, each lobe excavated medially to form two narrow loops. Seen from the ventral side, the cardinal process is also bilobed, but the two lobes are borne on a short thick shaft. The lateral ridges extending obliquely from the cardinal process are low and poorly developed. Just anterior to the cardinal process is the adductor field, which is elevated anteriorly as two lobes on each side of the posterior end of the brevisseptum. In a large specimen these lobes are excavated fairly strongly anteriorly, but in another specimen, probably more youthful, they have not yet formed. The brevisseptum is very well developed and forms an elongate triangle in side view, with a long gentle posterior side but a short steep anterior side. The anterior trail slopes are marked by short, delicate endospines.

That this genus belongs to the Linoproductidae there can be no doubt, but its exterior and interior combination of characters is unique for the family.

### *Undellaria magnifica*, new species

PLATE 467: FIGURES 14–29

Large, subcircular in outline, length and width nearly equal; hinge straight, narrower than midwidth; sides well rounded and anterior margin broadly rounded. Ears poorly developed, obtuse. Spines slender and delicate, thick along posterior margin, ears, and umbonal slopes, less concentrated elsewhere. Concentric undulations concentrated on ears and posterolateral slopes in both valves. No costellae.

Pedicle valve unevenly convex in lateral profile, maximum convexity posterior to midvalve, anterior slope long and gentle. Anterior profile broad, strongly convex dome with fairly even curvature. Beak small; umbonal region fairly strongly swollen, but region slightly posterior to middle strongly

inflated. Sides swollen and steep. Ears only slightly deflected.

Brachial valve flatly concave in posterior fourths, but with lateral and anterior margins deflected moderately in dorsal direction. Umbonal region moderately deep but flattening anteriorly. Posterolateral regions slightly convex.

Interiors as defined for genus.

MEASUREMENTS (in mm).—Thickness unmeasurable.

		brach- ial valve length	sur- face length	hinge width	mid- width	height
USNM 728e						
152783a	35.0	31.7	51.0	34.2	38.5	15.1
152783b	27.0	25.0	32.5	32.3	35.7	12.7
(holotype)						
152783c	?	23.2	24.0	23.0?	30.0	?

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation (10 feet above the base).

LOCALITIES.—USNM 728e, 728f.

DIAGNOSIS.—Large *Undellaria* with numerous spines along the posterior margin and ears.

TYPES.—Holotype: USNM 152783b. Figured paratypes: USNM 152783a, c, d. Measured paratypes: USNM 152783a, c.

COMPARISON.—No other species known to which this one can be compared.

DISCUSSION.—This large, thin-shelled linoproduc-tid is extremely rare in the Sierra Diablo which is the only region from which it is known. Only three valves in nearly complete condition were found, but parts of eight other individuals have been recovered.

### Genus *Grandaurispina* Muir-Wood and Cooper, 1960

*Grandaurispina* Muir-Wood and Cooper, 1960:305.—Williams et al., 1965:H472.

Moderately large and bulbous, thin shelled, pedicle valve strongly convex, brachial valve with nearly flat visceral area and sharply geniculated trail. Sides and anterior rounded; hinge equal to or narrower than midwidth. Ornament consisting of dimples, wrinkles, capillae, spine bases, and spines. Entire surface of pedicle valve except ears marked by radial capillae interrupted in groups by spine bases. Ears and sides wrinkled. Spines consisting of tuft of large, thick halteroid spines on the slope over each ear, row on posterior margin, and short oblique

spines attached to elongate bases arranged in quincunx. Brachial valve with prominent concentric wrinkles covering surface but indented by dimples corresponding to spine bases of opposite valve; entire surface except ear region covered by capillae. Spines long and hairlike, numerous, usually directed anteriorly but those on trail directed medially to hang over midvalve.

Pedicle valve interior without ear baffles; no adductor platform; diductor scars large and flabellate. Spines not produced into the interior, spine openings appearing as holes, flush with inner surface. Anterior papillose.

Brachial valve interior with small trilobed cardinal process, median lobe indented but not directed posteriorly; lateral ridges strong and forming posterior platform under cardinal process; median ridge low and narrow, extending anteriorly from cardinal process to join delicate brevisseptum; adductor scars lightly impressed, posterior pair dendritic. Trail slope with endospines generally small to moderately large.

TYPE-SPECIES.—*Grandaurispina kingorum* Muir-Wood and Cooper (1960: 306, pl. 121: figs. 1–13).

DIAGNOSIS.—Linoproduc-tidae having small body spines arranged in quincunx, large halteroid spines on the sides, and sessile trilobed cardinal process.

COMPARISON.—*Grandaurispina* is most like *Cancrinella* of all the Linoproduc-tidae but differs from it in the spine arrangement, especially the numerous short spines arranged in quincunx on the body of the pedicle valve and the enormous spines on the sides over the ears; moreover, the abundantly spiny brachial valve of *Grandaurispina* is very different from the sparse spines on *Cancrinella*.

DISCUSSION.—One of the major family characters of the Linoproduc-tidae is the finely costellate exterior. This feature is present on *Grandaurispina*, but it is somewhat modified by the extreme wrinkling and dimpling of both valves. On the pedicle valve the narrowly elongate spine bases which are arranged in quincunx interrupt the radial capillae or costellae. Consequently, the capillae are strongest in the swales lying anterior to the spine bases. On the brachial valve the dimples corresponding to the spine bases of the pedicle valve also interrupt the capillation. Thus the capillae on the high spots are the strongest and most clearly developed. The lateral extremities of both valves are generally devoid of capillation.

The spines may be divided into three kinds: halteroid spines of the lateral areas, halteroid spines along the posterior margin, and quincuncially arranged body or ornament spines. In some specimens the halteroid spines on the sides are numerous and ponderous, some attaining a length of 2 inches. Commonly these spines extend directly laterally and are often closely clustered. Usually five or six spines are present but several more may be added. The direction the spines take is not always lateral because many of them are at a high angle or even more than a right angle to the horizontal in a ventrolateral or directly ventrad direction. A few spines are directed posterolaterally. The lateral concentration and direction of the spines does not help in explaining their use, because they would not prevent rolling in most cases. They can be construed to have had that function when the spines are extended at a high angle in a ventral direction.

In most specimens spines appear along the posterior margin and on the extremity of the ear. The latter is usually a large spine, but the others are generally small. Numerous small spines appear with the cluster of large ones especially at the base of the umbonal slope near the beak.

The visceral disc, venter, and trail are made distinctive by the body spines and their conspicuous bases arranged in quincunx. This feature is so distinctive that the genus, at least in the Glass Mountains, can be detected from a shell fragment. In fact, Girty (1909) described two species of this genus from fragments. The spine bases are narrow and elongated, highest anteriorly, and the spine extends from the anterior higher part. The spine itself is short, slender, and usually slightly curved. It is given off at an angle of  $30^{\circ}$  to  $60^{\circ}$ . Some of the longer ones are pressed close to the valve surface, suggesting that they were recumbent, but this is probably due to crushing upon fossilization.

Two other features of the ornament merit notice, the wrinkles and the dimples. Wrinkles are not as prominent on the pedicle valve as they are on the other. Generally they are concentrated at the ears and umbonal slopes, but are indistinct on the visceral disc and trail. The wrinkling on the brachial valve is prominent and extends from the depression at the umbonal region over the entire valve. The wrinkles are strongest at the ears but become more subdued on the visceral disc and indistinct on the trail.

The wrinkles of the brachial valve are complicated and interrupted by numerous and prominent dimples that indent the surface between or on the wrinkles. The continuity of the wrinkles is broken by the dimple and thus forms an irregular node. The capillae occupy dimples and wrinkles alike. The spines of the brachial valve are given off at various angles, many of them almost at a right angle to the surface; especially is this true of those on the sides and trail, which overhang midvalve. These spines do not have expanded bases to form prominent nodes as those on the body of the pedicle valve. The shells of species of this genus are generally very thin, consequently the musculature of the pedicle valve is difficult to determine and is not preserved in the majority of specimens. The diductor scars are broad and flabellate and extend onto the sides of the valve to some extent. The adductor scars have a long posterior dendritic area, with the smooth scars located a short distance posterior to midvalve, but no trace of thickening or platforms was seen.

Another negative quality of the pedicle valve interior is the complete lack of ear baffles, a feature so prominent in many other productids. Generally the ears are small and are simply reflected laterally, enclosing a small triangular depression. No secondary material is laid across them and the position of the big lateral spines appears as open pits or holes.

The hinge of the pedicle valve is a straight line with no development of a ginglymus or other complication. The inside surface of the visceral disc area and trail in some is marked by numerous elongated pits corresponding to the spine bases of the exterior. These leave prominent and distinctive marks on internal fillings of the genus, as with *G. insignata* (Girty). Much of the inner surface of the trail and sides is coarsely granulose. Spines appear to have been sealed off by deposition across their proximal opening. In some, where a spine has arisen from a shell irregularity, the sealing plate will have a curved or semitubular form and thus simulate an internal spine like those seen in *Paucispinifera*. No specimens were seen, however, that have the development of inner spines such as those of the Marginiferidae or *Terrakea*.

As in other productids, the size of the shell is no indication of the stage of development of the interior; some large specimens have essentially immature structures whereas small ones may have thick



shells and well-formed interior details. The cardinal process of *Grandaurispina* is typically linoproducoid, triangular, and trilobed. The median lobe is incised vertically but not bent dorsally over or between the lateral lobes, as in the Marginiferidae. Furthermore, the median lobe is rugose throughout on its posterior face. The lateral lobes are narrow and curve to form a triangular chamber occupied by the median lobe. In some the lateral and median lobes may be nearly in contact. The cardinal process of immature specimens, except for being very narrow, appears to have the same features as that of adults.

The cardinal process in growth is rotated, from a position nearly at right angles to the hinge, to a high angle in larger specimens; this takes place in the development of the posterior platform formed by expansion of the lateral ridges. The cardinal process, in posterior view, appears to be supported by two lateral expansions from the posterior margin, and it may be further supported by a narrow longitudinal thickening that extends from the cardinal process and tapers to the brevisseptum, to the proximal end of which it is united. Thus the median support of the cardinal process appears to be one with the brevisseptum, but in actuality they are distinct structures.

The lateral ridges of *Grandaurispina* are its most conspicuous interior feature. They unite with and support the cardinal process, often to an extreme degree, extending obliquely laterally at a low angle to the posterior margin. They die out in the vicinity of the ears, in some specimens before reaching them, in others at the ears, and rarely, with the aid of fortuitous wrinkles, they cross the ears but are seldom evident on the sides anterior to the ear. The adductor field is large but is not strongly impressed in any of the species. The inner scars are small, narrow, and anterior to the posterior pair. These are large, dendritic, and lie posterolaterally to the smaller inner scars.

Brachial ridges are seldom well developed, but when present they descend in an anterolateral direction from their origin between the anterior and posterior adductor pairs and form a narrow loop just at the edge of the trail. The trail is granulose and endospinose, the larger spines being located near the place of geniculation.

**GROWTH.**—The smallest specimen of *Grandaurispina* (*G. kingorum* Muir-Wood and Cooper) mea-

sures 3 mm wide and slightly less in length. All of the immature ones are slightly wider than long. Spines are numerous and are about equal in length to valve length. The larger spines occupy the posterolateral extremities and long spines appear on the posterior margin. The umbo is misshapen and shows an incomplete attachment ring. With increasing age the specimens become progressively deeper; there is no place or zone of geniculation as in the Marginiferidae. At lengths between 10 and 15 mm the large lateral spines appear and make a strong contrast to the finer and more delicate ones of the body and posterior margin. With the development of the large spines the shell has become an adult. Capillae do not appear on the very young specimens. The smallest specimen in which they were identified was about 6 mm long. Specimens above this size usually are capillate but they are variable, and many specimens are not well enough preserved to show such fine details.

The smallest brachial valve, which is extremely thin and delicate, measures 3 mm long and 3.5 mm wide. In this specimen, and in those up to 6 mm in length, the cardinal process is bilobed and is supported by strong lateral ridges which are arched at the umbo. The cardinal process rests on the crest of this arch and is strongly bilobed. Beneath the cardinal process is a deep pit or antron. The ensemble is strongly reminiscent of the Productellidae.

As growth proceeds, the inside of each lobe coalesces to produce the median lobe, which is indented by a fissure at the line of junction. The antron exists until about 10 mm of length is achieved, after which it is obliterated by shell tissue in the growth of the lateral ridges and of the median ridge that grows anteriorly from the anterior end of the cardinal process. Above 10 mm of length these shells are essentially adult.

**CLASSIFICATION.**—This genus is placed in the Overtoniidae in the "Treatise on Invertebrate Paleontology" (1965:H472), but its characters are overwhelmingly linoproducoid. The ornament is strongly suggestive of *Canocrinella*. The cardinal process with its flattened median lobe and cuplike lateral lobes is entirely unlike that of the Overtoniidae.

**COMPARISON OF *Grandaurispina* AND *Terrakea*.**—Waterhouse (1971) has suggested that *Grandaurispina* and *Terrakea* are related, if not identical. We cannot agree with his thesis because we believe that,



although the two genera are homeomorphic, they have a different ancestry developed on different sides of the world. *Terrakea* in its usual manifestations is a much larger shell than *Grandaurispina*. Although the two appear similarly marked and spinose, there are significant differences. The lateral halteroid spines of *Grandaurispina* are ponderous in most species while those of *Terrakea* are generally less so. The body spines of *Grandaurispina* produce elongated bases on the outside of the shell like those of *Terrakea*, but the spines are not continued as tubes on the inside. Anterior to the spine bases of *Grandaurispina* are prominent rounded dimples in both valves; those of the pedicle valve are formed by the spine bases and those on the brachial valve are produced in complement to the bases on the pedicle valve. This dimpling is one of the chief features of *Grandaurispina* and is not seen in *Terrakea*, the outside of which is very much like that of *Cancrinella* or *Linoproductus*. The spines of the brachial valve of *Grandaurispina* are usually erect in the median part of the valve but around the margins the spines bend abruptly toward midvalve to hang over that part of the valve. Such spines were not observed in several species of *Terrakea* available for examination.

The interior of the pedicle valve of *Grandaurispina* shows few definite features, but the strong interior bumps that correspond to the external dimples are striking. The anterior inner slope also usually is fairly strongly endospinose. The interior of the brachial valve of *Grandaurispina* differs in its cardinal process and posterior region. The cardinal process is sessile, low, and trilobed, whereas that of *Terrakea* is the opposite, being erect and usually quadrilobed. The cardinal process of *Grandaurispina* is buttressed by an extravagant growth of the thick lateral ridges, which unite medially to form a broad triangular platform, in the apex of which the cardinal process is lodged. Seen from the exterior this platform protrudes strongly posterior to the hinge line. The cardinal process from this view shows a rugose myophore partly covered on the sides by the lateral lobes of the cardinal process. Muscle attachment was undoubtedly to the median myophore but probably also at its base within the chamber formed by the lateral lobes. In some specimens the lateral lobes also project laterally to emphasize the trilobed character of the structure. A specimen of *Terrakea*

*fragilis* (Dana) (USNM 3633e) shows a cardinal process bilobed in ventral view but quadrilobed in posterior aspect. The lateral lobes of this specimen are deeply divided medially to produce a four-pronged structure.

Waterhouse (1971, pl. 1: fig. 2) figured only one dorsal valve of his *Terrakea arctica*, an internal mold, but this only shows the slit in the ventral aspect of the cardinal process. His drawing (fig. 4, p. 357) is of the same view and is rather vague as to the features described above. This cardinal process seems not to belong to either genus as depicted. Two other points should be mentioned. The antron figured by Waterhouse in his drawing is not a constant feature of *Grandaurispina*. It appears in the young but is usually eliminated by growth of the posterior platform in adult *Grandaurispina*. The double median elevation is also an evanescent feature of *Grandaurispina*. In some specimens it is a single ridge; in some it seems to be a divided ridge; in others it is a simple ridge with another short ridge tentatively laid down beside it; and in a few specimens, no ridge is present at all. The brevisseptum, however, is a conspicuous feature in all of them.

From the above we conclude that *Terrakea* and *Grandaurispina* are different in morphological detail and that the two genera probably originated from different species of *Cancrinella*, one in Australia and one in North America.

### *Grandaurispina bella*, new species

PLATE 442: FIGURES 1-38

*Avonia meekana* R. E. King (not Girty), 1931:83, pl. 20: figs. 4, 5.

Small, wide to elongate, subquadrate to oval in outline; hinge usually less than midwidth; ears small; sides gently rounded; anterior margin narrowly rounded. Pedicle valve with two types of spines: ornament spines attached to anterior end of elongate spine bases, delicate and hairlike, attaining length of 7 mm on trail of adults; halteroid spines, slender and irregular in direction forming brush on umbonal and lateral slopes, reaching 10 mm in length. Capillae fine, difficult to see. Brachial valve exterior with strong concentric wrinkles, strongest on ears and anterior; spines numerous, delicate and hairlike.

Pedicle valve in lateral profile strongly convex in posterior half, but trail forming long, gently convex slope; anterior profile steep-sided dome with well-rounded top. Umbonal region gently swollen, not extending greatly posterior to hinge; median region strongly swollen. Trail commonly greatly elongated, spines becoming sparser on anteriormost parts. Ears small and not well defined.

Brachial valve deepest medially, geniculated at obtuse angle near midvalve, surface of trail strongly pitted anterior to zone of wrinkling; sides and anterior sloping steeply toward middle; ears small and slightly deflected.

Pedicle valve interior with no strongly defined features except prominent granulation on trail.

Brachial valve interior strongly convex, small cardinal process facing dorsad; lateral ridges well developed only in older specimens; ridge supporting cardinal process moderately developed; brevisep-tum short, not reaching midvalve; endospines unusually large for small shell; brachial ridges not seen.

MEASUREMENTS (in mm).—Thickness of USNM 149988p, 4.0; of others unmeasurable.

	brach- ial valve length	sur- face length	hinge width	mid- width	height
USNM 706					
149988a (holotype)	21.7	?	36.0	16.9	11.0
149988b	22.0	?	38.0	13.9	11.2
149988c	17.6	?	30.0	14.3	9.2
149988d	18.1	?	28.0	15.7	8.2
149988e	17.9	?	31.0	16.9	10.3
149988f	16.2	?	29.0	16.0	9.4
149988p	16.2	13.7	26.0?	13.6	8.0

STRATIGRAPHIC OCCURRENCE.—Word Formation (Willis Ranch and Appel Ranch members).

LOCALITIES.—Willis Ranch: USNM 706, 706e, 724u. Appel Ranch: 714o.

DIAGNOSIS.—Small, elongate *Grandaurispina* with numerous small body spines and delicate halteroid spines.

TYPES.—Holotype: USNM 149988a. Figured paratypes: USNM 149988b, g–j, p; 149989a, b. Measured paratypes: USNM 149988b–f, p. Unfigured paratypes: USNM 149988c–f, k–o.

COMPARISONS.—This is a small species that strongly suggests some species of *Krotovia* Freder-

icks. Its rounded form and slender spines are distinctive. It is not likely to be confused with any other Glass Mountains species because of its size and the close spacing of the spines and spine nodes. The young of *G. kingorum* Muir-Wood and Cooper have a similar form, but the spacing of the nodes is more distant and they are considerably larger than those of *G. bella*. The profile and outline of *G. belliformis*, a new species from the Guadalupe Mountains, and of *G. rara*, a new species from the Glass Mountains, are like those of *G. bella*, but the spine nodes of these species are coarse and distant.

*Grandaurispina bella* is a rare species, best known from the lower part of the Willis Ranch Member of the Word Formation. Four specimens have been identified from the upper part of this member at USNM 706e. King (R. E., 1931:83) records it from only two localities and lists it as rare at one of them.

This species was assigned by King to Girty's species *Productus meekanus*. The problems connected with identification of that species are discussed under *G. meekana*.

### *Grandaurispina belliformis*, new species

PLATE 442: FIGURES 39–45

Small, elongate, elliptical in outline, length greater than width; sides broadly rounded; anterior margin narrowly rounded. Surface marked by fine concentric wrinkles at ears of both valves. Pedicle valve without capillae, so far as can be ascertained, but with elongated spine bases well scattered over surface in crude quincunx. Halteroid spines forming tuft over each ear, length not known. Brachial valve exterior with strong concentric wrinkles on anterior half interrupted by large dimples corresponding to spine bases of opposite valve; entire surface covered by hairlike spines.

Pedicle valve lateral profile with most convexity in posterior third, anterior two-thirds forming long trail slope. Anterior profile narrowly domed and with steep sides. Umbonal region swollen, protruding for short distance posterior to posterior margin. Median and anterior regions swollen. No sulcus. Ears small, inconspicuous, without baffles. Muscle marks of interior lightly impressed.

Brachial valve deeply concave, deepest medially, posterolateral extremities somewhat flattened. Ge-

niculation occurring near midvalve; sides and anterior steeply sloping. Ears not formed.

Brachial valve interior with small cardinal process, delicate lateral ridges; posterior platform moderately thickened. Ridge supporting cardinal process moderately thick; brevisseptum short, not reaching midvalve. Trail slope strongly granulose and endospinose; endospines large for small shell.

MEASUREMENTS (in mm).—From locality USNM 728, specimens 149983a (holotype) and 149983b, respectively: length 21.5, (?); brachial valve length (?), 16.9; surface length 38.0, (?); hinge width 16.8, 16.6; midwidth 18.7, 20.5; height 11.6, (?); thickness unmeasurable.

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member).

LOCALITY.—USNM 728.

DIAGNOSIS.—Small, elongate *Grandaurispina* having strong, distant spine nodes.

TYPES.—Holotype: USNM 149983a. Figured and measured paratype: USNM 149983b.

COMPARISON.—This species is only comparable to *G. bella*, new species, from which it is distinguished by the large and distant nodes on the pedicle valve.

*Grandaurispina crassa*, new species

PLATE 438: FIGURES 1–33; PLATE 443: FIGURES 24–31

*Avonia signata* R. E. King (not Girty), 1931:83, pl. 20: figs. 19, 21, 22, 23a, b, 24a, b.

Large, subquadrate to longitudinally rectangular, usually somewhat elongate; hinge equal to or less than midwidth; sides nearly straight or gently rounded; anterior margin broadly rounded. Ears small, rectangular or nearly so.

Surface costellate and nodose. Spines of two kinds; ornament spines attaining length of nearly 10 mm, attached to prominent elongate bases, crudely arranged in quincunx; halteroid spines in masses or tufts on lateral slopes, ears, and posterior margin, usually long and thicker than ornament spines. Brachial valve wrinkled and dimpled, especially on ears, and strongly spinose, larger spines extending medially from ears and sides.

Pedicle valve bulbous, trail long; lateral profile with greatest curvature in umbonal region; trail with long convex slope. Anterior profile high flattened dome with precipitous sides. Median region inflated; umbonal region strongly swollen and protruding considerably posterior to hinge. No sulcus.

Brachial valve gently concave to place of geniculation, there abruptly bent at nearly right angle; sides steep and trail steep and long. Ears gently deflected, flattened.

Pedicle valve interior with transversely elliptical diductor scars and broad dendritic adductor patch. No ear baffles.

Brachial valve interior with prominent posterior platform formed by strong lateral plates; cardinal process large, erect, with myophore facing in dorsad

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 715i							
150018a	26.6	?	57.0	26.6	27.5	17.0?	?
150018b	27.7	?	51.0?	24.6	25.8	?	?
150018c	24.4	17.2	52.0	25.1	26.9	15.5	8.4
(holotype)							
150018d	18.0	?	46.0	20.7	23.0	?	?
150018e	20.8	?	42.0	21.6	19.8	13.0	?
150018f	20.0	?	18.8	18.8	21.7	10.0	?
150018g	17.8	?	26.0	16.6	20.0?	7.9	?
150018h	22.2	?	43.0	18.8	22.8	13.2	?
150018i	15.6	?	25.0	14.2	17.2	7.0	?
150018k	36.9	?	70.0?	26.7	30.8	?	?
USNM 706d							
150016a	29.7	20.6	61.0	25.3	25.7	19.0	12.0
150016b	27.7	16.8	56.0	26.4	25.0	18.0	10.0
150016c	23.8	16.0	50.0?	?	?	?	11.7
150016d	20.8	17.0	37.0	15.8	21.5	12.3	6.0

direction in adults. Median ridge from cardinal process long, moderately high and narrow, tapering to join delicate brevisseptum. Posterior adductor scars strongly dendritic. Brachial ridges rarely thickened even in old specimens.

STRATIGRAPHIC OCCURRENCE.—Word Formation (Appel Ranch Member and lens just below).

LOCALITIES.—USNM 706d, 714o, 715i, 719z, 722t, 726t, 727j. Lens: 742b.

DIAGNOSIS.—Large *Grandaurispina* with strong distant nodes and fine costellae.

TYPES.—Holotype: USNM 150018c. Figured paratypes: USNM 150016a, d; 150018i, k, p, q; 153891; 153894; 153897a, b. Measured paratypes: USNM 150016a–d; 150018a, b, d–i, k. Unfigured paratypes: USNM 150016b, c; 150018a, b, d–h, j, l–o.

COMPARISONS.—The large size of this species makes it comparable to *G. kingorum* Muir-Wood and Cooper and to *G. gibbosa*, new species, but it is readily distinguished from these two by the large spine nodes and the great strength of the fine radial ornamentation. In the latter respect it is likely to be confused only with *G. rudis*, new species, from the Guadalupe Mountains. This latter species, however, does not attain the large size of *G. crassa*, is not so strongly radiated, nor does its umbonal region protrude as far beyond the posterior margin as in *G. crassa*.

DISCUSSION.—*Grandaurispina crassa* is fairly common in the Appel Ranch Member, uppermost limestone of the Word Formation. It is common in cherty debris weathered from the limestone, occurring in the form of internal fillings that retain fairly strong impressions of the nodes and the stronger radial ornament. The species attains a large size and in its maximum form is strongly elongated. No specimens of *G. rudis* have been seen which attain the large size and elongate form of *G. crassa*.

*Grandaurispina elongata*, new species

PLATE 441: FIGURES 1–26

Elongate oval in outline, hinge normally narrower than midwidth; sides rounded; anterior margin narrowly rounded; ears small and inconspicuous. Surface marked by indistinct capillae, spine bases, and spines. Lateral slopes marked by few large halteroid spines attaining length of 35 mm; body of shell marked by short curved spines

(4 mm) arising from anterior end of elongate bases; spine bases small and fairly crowded.

Pedicle valve lateral profile with posterior third narrowly curved; anterior two-thirds forming long convex slope. Anterior profile narrowly rounded dome with steep sides. No sulcus. Umbonal region swollen and extending considerably posterior to posterior margin. Median region swollen. Umbonal slopes steep. Interior with trail surface strongly granulose.

Brachial valve deeply concave, greatest concavity near place of geniculation at about midvalve. Anterior slope and sides steep. Ears insignificant, shown only by slight ventrad deflection of cardinal extremities. Posterolateral regions strongly wrinkled; wrinkles on visceral region and trail dappled by numerous small dimples corresponding to spine bases of opposite valve. Hairlike spines numerous over whole surface.

Brachial valve interior with strong lateral ridges forming prominent posterior platform for fairly large cardinal process. Ridge supporting cardinal process variously developed. Brevisseptum reaching about to midvalve. Trail slope covered by numerous small endospines.

MEASUREMENTS (in mm).—Thickness unmeasurable.

		<i>brach- ial valve length</i>	<i>sur- face length</i>	<i>hinge width</i>	<i>mid- width</i>	<i>height</i>
USNM 706e						
150005a (holotype)	33.2	?	58.0	25.4	23.0	17.3
150005b	27.0	?	52.0	26.0	26.2	16.0?
150005c	27.3	?	49.0	25.8	24.7	16.0
150005d	25.5	?	46.0	19.4	22.3	14.7
150005e	24.4	?	46.0	22.4	21.7	14.1
150005f	28.3	?	53.0	26.6	26.0	16.4
150005g	?	16.0	?	23.0?	21.7	?
150005h	?	16.0	?	18.0	20.3	?

STRATIGRAPHIC OCCURRENCE.—Word Formation (Willis Ranch Member).

LOCALITY.—USNM 706e.

DIAGNOSIS.—Elongate and finely nodose *Grandaurispina*.

TYPES.—Holotype: USNM 150005a. Figured paratypes: USNM 150005b, c, g, h; 153892. Measured paratypes: USNM 150005b–h. Unfigured paratypes: USNM 150005d–f.

COMPARISON.—This species differs from *G. kin-*

*gorum* Muir-Wood and Cooper with which it occurs, in its elongate shell and the generally finer and more closely spaced spine bases.

***Grandaurispina gibbosa*, new species**

PLATE 440: FIGURES 1–36; PLATE 441: FIGURES 27–37

Medium size for genus, length and width about equal or length slightly greater in large specimens; sides gently rounded; anterior margin broadly rounded. Ears small, pointed, usually acute, but nearly right angle or obtuse angle depending on age. Surface nodose and capillate, 6 or 7 capillae in 2 mm on trail of adult. Spines of two kinds; halteroid spines forming brush on slope over each ear, attaining length of 30 mm, many extending laterally but others at various angles in ventrad direction; ornament spines occupying anterior side of elongate bases, not crowded, attaining length of 5 mm or less at anterior margin of adult.

Pedicle valve with well-rounded lateral profile, posterior half having greater convexity, anterior half forming long, moderately convex slope. Ante-

rior profile high, flattened dome with precipitous sides. Sulcus, usually inconspicuous but broad, shallow, median depression present on some specimens. Median region inflated; umbonal region swollen, extending posterior to hinge.

Brachial valve fairly strongly concave, posterior two-thirds less so than anterior third at geniculation; deepest just anterior to place of geniculation. Flattened at small ears. Sides and anterior long and steep. Surface strongly wrinkled at ears and dimpled over whole surface of visceral region.

Pedicle valve interior without ear baffles or notable thickening at posterior. Muscle scars lightly impressed.

Brachial valve interior strongly wrinkled to pustulose; lateral ridges moderately developed, forming short posterior platform for small cardinal process. Median ridge from cardinal process indifferently formed, well developed in some specimens, poor in some, and absent in still others. Brachial ridges only in obese specimens; posterior adductor scars strongly dendritic. Brevisseptum delicate. Endospines small, commonly on crest of interior wrinkles and nodes.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706b							
150004a	31.0	?	61.0	28.1	30.0	19.2	?
150004b	30.0	?	58.0	26.8	28.7	18.0	?
150004c	28.3	25.0	61.0	27.5	27.0	19.6	8.3
150004d	25.5	?	53.0	29.2	25.7	17.0	?
150004e	24.5	16.9	53.0	25.1	26.9	17.0	9.0
(holotype)							
150004f	23.2	17.0	46.0	26.3	24.5	14.6	5.3
150004g	23.0	16.8	45.0	23.2	24.3	14.7	7.7
150004h	23.2	16.3	40.0	24.5	24.9	11.4	4.8
150004i	20.0	?	40.0	23.0	22.3	13.5	?
150004j	18.5	?	35.0	20.6	22.0	12.0	?
150004k	15.0	13.4	27.0	16.0	20.0	13.8	4.0
150004l	11.3	?	17.0	8.8	14.0?	5.4	?
150004m	9.7	?	12.0	?	10.5	3.0	?

STRATIGRAPHIC OCCURRENCE.—Word Formation (limestone lenses between Willis Ranch and Appel Ranch members).

LOCALITIES.—USNM 706b, 732c, 737w, 741p.

DIAGNOSIS.—*Grandaurispina* of medium size,

strongly convex, moderately strongly nodose, and with moderately thick halteroid spines.

TYPES.—Holotype: USNM 150004e. Figured paratypes: USNM 150003a–f; 150004b, d, g, l; 153893a, b. Measured paratypes: USNM 150004a–d,



f-m. Unfigured paratypes: USNM 150004a, c, f, h-k, m.

COMPARISONS.—This species is common in a lens lying not far stratigraphically above the Willis Ranch Member of the Word Formation. *Grandaurispina gibbosa* is abundant and is directly comparable to *G. kingorum* Muir-Wood and Cooper which it approaches in size but from which it differs in ornament and proportions.

*Grandaurispina gibbosa* in its largest size appears to be somewhat smaller than the largest specimens seen of *G. kingorum* which, with *G. crassa*, new species, attains the largest size for the genus. Length and width of *G. gibbosa* tend to be more alike for *G. crassa* than *G. kingorum*, the midwidth of which, tends to be considerably greater than the length. The ornament of *G. gibbosa* is stronger than that of *G. kingorum*, the spine nodes being somewhat stronger and the capillae stronger. The large halteroid spines of *G. gibbosa* are less ponderous than those of *G. kingorum*.

The collection of *G. gibbosa* is large, but not so large as that of *G. kingorum*. Variation of form seems less strong in *G. gibbosa* than in *G. kingorum*, in which variation is very common not only in shape, which is to be expected, but also in ornament. The greater uniformity of *G. gibbosa* is apparent when large numbers of these species can be seen together.

### *Grandaurispina kingorum* Muir-Wood and Cooper

PLATE 436: FIGURES 1-26; PLATE 437: FIGURES 1-32; PLATE 439: FIGURES 1-5

*Avonia signata* R. E. King (not Girty), 1931:83, pl. 20: figs. 16a, b, 17a, b, 20.

*Grandaurispina kingorum* Muir-Wood and Cooper, 1960:306, pl. 121: figs. 1-13.

Large, subrectangular, width slightly exceeding length in majority of specimens; hinge equal to or narrower than midwidth. Sides gently rounded; anterior margin broadly rounded, but nasute in large specimens. Ears pointed, not prominent, slightly acute to slightly obtuse. Surface variable, marked by numerous spine bases ranging horizontally on mid-trail, 3 to 5 per 10 mm; capillae fine and difficult to discern, numbering 4 or 5 per mm on trail of pedicle valve of holotype and 4 to 6 per mm on brachial valve. Lateral spines long, thick, attaining length of

nearly three inches (48 mm), and thickness of 2.5 mm. Large spines generally directed laterally but may be in any other direction. Body spines of adults, short, curved, usually attaining length of 2-6 mm, with shorter, stouter spines generally on older shells.

Pedicle valve lateral profile strongly convex, greater convexity in posterior third, median third (venter) strongly rounded, but trail forming long moderately convex slope. Anterior profile broad and high dome, flattened on top and with steeply sloping sides. Beak small; umbonal region swollen; median region greatly inflated and with steep lateral slopes. Sulcus scarcely defined and, when present, broad and shallow.

Brachial valve with shallow concave umbonal region; posterior two-thirds of valve gently concave, strongly and closely dimpled and with strong concentric wrinkles; geniculation strong at anterior third to produce steep trail about one-third brachial valve length. Spines long and slender, attaining length of 20 mm. Spines on ears thicker than others and directly medially.

Pedicle valve interior with widely flabellate diductor scars and fairly wide adductor patch with posterior scars dendritic. No ear baffles.

Brachial valve interior with strong lateral ridges descending obliquely toward ears; posterior platform well developed; cardinal process small, trilobed. Brevisseptum usually delicate and low in some specimens united to cardinal process by low ridge. Endospines small, in groups on elevations produced internally by rugae and pits of exterior.

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank and Willis Ranch members).

LOCALITIES.—China Tank: USNM 706c, 706z, 713, 726r. Willis Ranch: AMNH 505, 506; USNM 706, 706e, 723t, 723w, 724u, 735c.

DIAGNOSIS.—*Grandaurispina*, finely capillate, bulbous and with large lateral halteroid spines in a tuft.

TYPES.—Holotype: USNM 123454. Figured paratypes: USNM 123455c-e, g. Unfigured paratypes: USNM 123455a, b, f. Figured hypotypes: USNM 14999a-k, m; 152784c; 153887a-d; 153888b, c; 153889a, b, g, h; 153890a-g. Measured hypotypes: USNM 149995a-w, 152784a-h.

COMPARISON.—*Grandaurispina kingorum* will not not be confused with *G. rudis*, new species, of the Guadalupe Mountains because the ornament of

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706e							
123454	31.0	22.7	56.0	34.0	34.0	22.0	14.0
(holotype)							
149995a	31.0	?	58.0	33.0	34.0	19.0	?
149995b	30.6	?	54.0	27.8	32.4	16.9	?
149995c	31.0	?	58.0	30.3	32.0	17.6	?
149995d	30.6	?	58.0	31.0	30.3	18.8	?
149995e	27.2	?	50.0	29.1	31.5	16.0	?
149995f	28.0	?	52.0?	24.3	28.8	16.9	?
149995g	30.6	?	57.0	29.1	29.0	17.8	?
149995h	25.0	?	45.0	28.0	28.6	14.2	?
149995i	25.2	?	49.0	29.4	29.4	15.9	?
149995j	22.6	?	39.0	23.7	25.7	12.6	?
149995k	22.3	?	40.0	30.0	27.0	13.0	?
149995l	19.7	?	36.0	22.0	26.1	12.0	?
149995m	19.6	?	32.0	21.0	26.2	10.0	?
149995n	18.8	?	32.0	19.5	22.6	9.5	?
149995o	15.7	?	25.5	18.5	21.3	7.8	?
149995p	15.0	?	22.0	14.5	18.9	7.1	?
149995q	14.1	?	21.0	13.2	17.3	6.7	?
149995r	12.2	?	17.0	12.7	15.8	5.1	?
149995s	9.8	?	13.0	10.2	12.3	4.1	?
149995t	10.2	?	15.1	6.3	12.2	3.7	?
149995u	8.2	?	12.0	7.9	9.8	3.2	?
149995v	37.0	?	68.0	30.4	35.6	23.7	?
149995w	29.7	?	52.0	26.8	28.0	16.6	?
USNM 706							
152784a	23.8	18.7	42.0	26.1	26.0	14.6	8.0
152784b	22.9	17.0	44.9	25.0	25.4	14.0	6.0
152784c	23.6	16.4	48.0	28.0	29.0	16.8	8.0
152784d	21.6	15.3	41.0	23.7	23.0	13.0	6.0
152784e	21.8	17.7	39.0	28.1	27.6	12.0	7.2
152784f	20.3	14.5	40.0	22.6	25.0	13.2	5.7
152784g	17.9	15.0	28.5	20.0	20.8	9.4	5.8
152784h	17.8	15.0	28.0	17.8	24.0	8.4	4.7

that species is so much stronger. It will not be confused with *G. signata* (Girty) from the same region because of the few and very distant spine bases and body spines. It is distinguished from *G. elongata*, new species, with which it occurs, by its more transverse form and the later geniculation of the brachial valve, which in *G. kingorum* is almost flat for a distance nearly equal to the length of the brachial valve of *G. elongata*.

DISCUSSION.—Some of the largest specimens of this species exhibit a tendency toward a nasute fold at the middle of the anterior margin.

Variation of the external form is to be expected in any of the productids that were subject to

currents that could waft them from one place to another. Some specimens of *G. kingorum* are fairly elongated, but generally their midwidth is greater than the length. The hinge is variable but in the majority of specimens slightly exceeds the length. Variation also occurs in the ornament. The capillae are generally not well preserved, but where they can be seen they are not uniform on the same specimen. The spines and spine nodes are variable as to size, number, and spacing. A few specimens have very distant spine bases, but none of the specimens approaches *G. signata* (Girty) in this respect. A few specimens have unusually small spine bases and spines for the species and thus approach *G. elongata*.

*Grandaurispina meekana* (Girty)

PLATE 443: FIGURES 1, 2

*Productus meekanus* Girty, 1909:263, pl. 30: figs. 13, 13a.

Girty figured a single specimen of this species which has very distinctive ornamentation. The specimen is said to have come from Comanche Canyon, Glass Mountains, Texas (USGS 3763). Although Girty mentioned the wrinkling on the ears and the fact that the ears are small, the illustrated specimen does not preserve the ears. Furthermore, none of the lateral or anterior margins are preserved. Girty emphasized the tear shape of the spine bases and the capillae between and interrupted by them. The ornamentation of this specimen is clearly that of *Grandaurispina*, but it is impossible to identify it with any of the Glass Mountains species. Girty's restored outlines are definitely inaccurate because the genus in all its known species is strongly umbonate, with the umbonal region projected beyond the posterior margin.

R. E. King (1931:83) assigns to *G. meekana* small specimens of *Grandaurispina* having size and outline similar to Girty's restoration. Rather than accept King's identification, we have described King's specimens and similar ones from the lower part of the Word Formation (Willis Ranch Member) as the new species, *G. bella*. We followed this course because *G. bella* is more convex in lateral profile, is more umbonate, and does not have the prominent ornament of Girty's specimen. Furthermore, the spine bases of *G. bella* are smaller and more delicate than those of *G. meekana*.

Comparison of *G. meekana* with *G. crassa*, new species, of the Appel Ranch Member shows the two to be completely unlike. The ornamentation of *G. meekana* is similar to that of *G. gibbosa*, new species, or *G. kingorum* Muir-Wood and Cooper, but it is impossible to identify any other features in common between the three species. The outline and profiles of *G. meekana* are purely conjectural, unidentifiable with these two Word species.

The location of Comanche Canyon in the Glass Mountain is uncertain but the mileage from Marathon and the fossils figured from there suggest that it is the canyon leading northeast from a point a mile north of the Hess Ranch house up to Old Word Ranch and Split Tank. If this be Comanche Canyon, *G. meekana* must have come from the Road

Canyon Formation, the China Tank Member or Willis Ranch Member of the Word Formation, or the Cathedral Mountain Formation, all of which are exposed in it. The genus is very rare in the Cathedral Mountain and Road Canyon formations. The likeliest source of *G. meekana* is from the China Tank or Willis Ranch member.

In view of all the uncertainties, it seems futile to attempt to employ Girty's name. This cannot be done with accuracy and the name will never have any stratigraphic value. It is best to leave it on the type specimen and not to try to identify it further with the superb material of *G. gibbosa* and *G. kingorum*, either of which names it may preoccupy.

Types.—Holotype: USNM 118532.

*Grandaurispina rara*, new species

PLATE 443: FIGURES 3-23

Outline quadrate in young but becoming elongate elliptical in adults. Hinge generally narrower than midwidth. Sides rounded, anterior margin narrowly rounded. Ears inconspicuous. Surface without capillae but with two types of spines: halteroid spines slender but generally thicker than body spines and concentrated in tuft over each ear; ornament spines short, arising from anterior ends of elongate spine bases usually closely crowded. Brachial valve with crowded hairlike spines.

Pedicle valve lateral profile having umbonal region and venter strongly bent; trail long and with moderate slope. Anterior profile forming narrowly rounded dome with very steep sides. Median region inflated. No sulcus. Interior without strongly

MEASUREMENTS (in mm).—Thickness unmeasurable.

	<i>brach- ial valve length</i>	<i>sur- face length</i>	<i>hinge width</i>	<i>mid- width</i>	<i>height</i>	
USNM 715i						
149984a	23.6	?	40.0?	13.4	17.5	11.3?
149984b	21.9	?	38.0	14.8	16.0	10.5
149984c	24.0	?	43.0	17.9	19.2	12.0
149984d	19.0	?	33.0	17.3	21.5	9.6
149984e	?	20.7	?	19.6	23.0	?
149984f	?	18.3	?	18.2	21.8	?
USNM 719z						
154895a (holotype)	20.7	?	35.0	15.0	19.9	11.0

impressed structures.

Brachial valve geniculated at about midvalve, deepest just posterior to place of geniculation; trail moderately steep; sides low and sloping steeply. Surface ornamented by strong concentric wrinkles on ears; concentric wrinkles interrupted by dimples to give surface a dappled effect.

Brachial valve interior with small cardinal process, well-developed lateral ridges; posterior platform moderately developed; ridge supporting cardinal process strong; brevisseptum not reaching midvalve. Endospine large and numerous; trail slope granulose.

STRATIGRAPHIC OCCURRENCE.—Word Formation (Appel Ranch Member).

LOCALITIES.—USNM 715i, 719z, 722t.

DIAGNOSIS.—Quadrate to elongate *Grandaurispina* having numerous fairly strong spine bases on the body of the pedicle valve.

TYPES.—Holotype: USNM 153895a. Figured paratypes: USNM 149984e; 153895b, e; 153896. Measured paratypes: USNM 149984a–f. Unfigured paratypes: USNM 149984a–d, f; 153895c, d.

COMPARISON.—This species has the form of *G. bella* and *G. belliformis*, both new, but it has more numerous spines than the latter and less numerous and stronger spines than *G. bella*. It is thus intermediate between the two.

This species is rare and has been found only in the upper part of the Word Formation. The available specimens are not good because all of the pedicle valves have been crushed or distorted. The brachial valves, on the other hand, appear to be in nearly perfect condition.

### *Grandaurispina rudis*, new species

PLATE 439: FIGURES 6–29

Medium size for genus, length and width nearly equal; hinge less than midwidth. Sides gently rounded; anterior margin broadly rounded. Ears small and inconspicuous, nearly rectangular. Surface posteriorly costellate, costellae numbering 5 or 6 per 5 mm on trail. Spines of two kinds; tuft of thick and long spines on lateral slopes over each ear, but spine length not known; and short, stout, curved body or ornament spines arising from anterior end of tear-shaped prominent nodes, widely spaced and crudely arranged in quincunx.

Pedicle valve moderately convex in lateral pro-

file, posterior third or umbonal region being most curved, median third strongly curved, but anterior third or trail moderately convex. Anterior profile strongly domed, top of dome flattened and sides nearly vertical. Sulcus indifferently developed, broad and shallow when present. Umbonal region swollen and protruding considerably beyond posterior margin. Median region inflated. Umbonal slopes steep.

Brachial valve nearly flat over most of surface but with anterior third sharply geniculated and forming short trail. Umbonal region shallowly depressed; ears flattened and deflected toward pedicle valve. Sides and anterior nearly vertical. Ears and sides strongly wrinkled; costellae strongly developed. Entire valve surface covered by mat of fine spines, those on sides and trail growing medially, others nearly vertical.

Pedicle valve interior with muscle field large, scars strongly impressed. Inner surface of trail strongly and coarsely granulose.

Brachial valve interior with moderately developed lateral ridges extended as low baffles across ears; posterior platform not strongly developed. Cardinal process supporting ridge lightly formed; brevisseptum long. Cardinal process variable, generally small. Brachial ridges not formed.

MEASUREMENTS (in mm.).—Thickness unmeasurable.

	brach- ial valve length	sur- face length	hinge width	mid- width	height
USNM 728					
150008a	23.6	?	45.0	23.0	25.6
150008b	?	16.2	?	22.4	23.4
150008c	27.7	?	53.0	21.8	23.8
150008d	22.1	?	44.0	23.0	23.3
150008e	28.8	?	55.0	24.2	26.5
150008f	25.1	?	50.0	26.6	26.3
150008h (holotype)	31.6	?	55.0	29.0	32.5

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member).

LOCALITIES.—AMNH 512, 519; USNM 728.

DIAGNOSIS.—Medium-sized *Grandaurispina* having costellae and large spine bases.

TYPES.—Holotype: USNM 150008h. Figured paratypes: USNM 150008a, b, d, g. Measured paratypes: USNM 150008a–f. Unfigured paratypes: USNM 150008c, e, f.

COMPARISON.—Comparison of this species with *G. crassa*, new species, from the Glass Mountains is made under the latter species. This is the only species to which comparison should be made because the ornament is so much coarser than that of any other species.

*Grandaurispina signata* (Girty)

*Productus signatus* Girty, 1909:263, pl. 22: figs. 4, a, b.

Girty's type-specimen (USNM 118533) is a fragment preserving only part of one side and all of the anterior margin; the umbonal region and ears are completely missing. Adding to this the fact that the specimen is an inner filling, or dolomite cast, of the interior, we are faced with an extremely difficult problem in identifying the species in another type of preservation. The only redeeming feature is that the position of the spine nodes is well impressed on the type specimen and some idea of their spacing and size can be obtained. These are the features on which the species and its recognition have been based. King (1931:83) identified Girty's species in the Glass Mountains, evidently using the distant quincuncial arrangement of the spines as the means of identification. Under this name were placed specimens of *G. kingorum* Muir-Wood and Cooper and *G. crassa*, new species, neither of which is really conspecific with the Guadalupe form. In fact, the better material now available from the Glass Mountains indicates that this species does not occur there.

*Grandaurispina signata*, by virtue of the distant arrangement and large size of the spine bases is unlike any other *Grandaurispina* from that region. It is quite different from *G. rudis*, new species, which is smaller, squarer, much more coarsely ornamented, and with more closely spaced spine bases.

*Grandaurispina signata* is not only different from all of the Glass Mountains species, but we are unable to identify any of our Guadalupe specimens with it. The large new species *G. rudis* is like it in size and distribution of spines. This species is costellate as well as capillate, but none of these characters shows on the interior impression which is Girty's type. We are again in the position of recommending that a name be left with a type specimen because the specimen is inadequate both

in preservation and source. Girty's type of *G. signata* comes from some level in the Delaware Mountain Formation at the entrance to Guadalupe Canyon.

*Grandaurispina undulata*, new species

PLATE 442: FIGURES 46-55

Large, bulbous, width greater than length; outline subrectangular; hinge narrower than midwidth. Ears small and inconspicuous, nearly at right angle. Sides gently rounded; anterior margin broadly rounded. Surface finely capillate, with 3 or 4 capillae in 2 mm on trail and concentric lamellae on umbonal region. Spines of two kinds; halteroid spines of large size mostly extending laterally but some at almost any high angle to shell surface in ventrad direction. Length of halteroid spines not known but probably more than 40 mm. Ornament spines arising from prominent, widely scattered, elongate bases; ornament spines gently curved, arising at angle of between 30° and 60°, attaining length of 6-8 mm.

Pedicle valve lateral profile narrowly convex in umbonal region, but with long trail slope; anterior profile high, flat-topped dome with steep sides. Sulcus not formed. Midregion swollen; umbo swollen and extended considerably posterior to posterior margin. Trail long and steep. Interior with lightly impressed muscle scars; spines showing as elongate impressions; interior of trail granulose.

Brachial valve moderately concave in anterior two-thirds but becoming abruptly geniculated in anterior third; surface strongly undulated concentrically. Cardinal process short and low; brevisep-  
tum short and inconspicuous, extended posteriorly to cardinal process.

MEASUREMENTS (in mm).—From locality USNM 732, specimens 150010a (holotype) and b, respectively: length 22.8, 20.4; surface length 45.0, 42.0; hinge width 20.2, 22.3; midwidth 23.4, 22.7; height 13.4, 13.0; brachial valve length, thickness, unmeasurable.

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member).

LOCALITIES.—AMNH 21, 496, 600; USNM 730, 732.

DIAGNOSIS.—Large spreading *Grandaurispina* with few and distant body spines having long bases.



**TYPES.**—Holotype: USNM 150010a. Figured paratypes: USNM 150010b, c. Measured paratype: USNM 150010b.

**COMPARISON.**—This species is unlike *G. rudis*, a new species that also occurs in the Getaway Member, in not having the strong costellae that appear on most parts of *G. rudis*. Among Glass Mountains forms this species is smaller and less inflated than either *G. kingorum* Muir-Wood and Cooper or *G. gibbosa*, new species. It is larger than *G. bella*, new species, and is much more distantly spinose than *G. rara*, new species.

*Grandaurispina? vaga*, new species

PLATE 435: FIGURES 1–32

Large for genus, subquadrate in outline, generally slightly wider than long; sides gently rounded; anterior margin broadly curved; ears moderately developed, generally approximating right angle; anterior commissure without folding; surface of pedicle valve smooth except for growth lines and spine bases; ornament spines long, slender and curved, protruding from shell surface from small,

but elongated, bases rudely arranged in rows; no simulation of costation; halteroid spines, long and irregular, forming dense tuft on lateral slopes and attaining length of 35 mm. Brachial valve surface marked by dimples and fine, irregular hairlike spines.

Pedicle valve fairly evenly and moderately convex, with maximum height in midregion; anterior profile broadly domed and with steeply sloping sides. Umbonal region not greatly extended posterior to hinge line; beak small, inconspicuous. Umbonal region broadly swollen and passing into the inflated midvalve region; anterior and lateral slopes nearly equally steep.

Brachial valve deeply concave, most concave in median region; umbo forming broadly shallow depression bounded by gradual rise of shell to ears; lateral and anterior rims steep; ears small, angular, and demarcated by anterior notch.

Pedicle valve interior with adductor field not thickened and ears not demarcated by baffles. Brachial valve interior with bulbous myophore and short, medially grooved shaft braced by thick median ridge; median lobe of myophore thick, not recurved; anterior slope with minute endospines.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702							
152785a	13.9	10.2	26.0	14.4	15.1	8.3	4.7
USNM 702un							
152786a	17.7	12.9	36.0	19.0	19.4	10.7	6.0
(holotype)							
152786b	18.8	13.6	36.0	20.0	18.5	12.0	5.7
152786c	15.5	15.5	?	29.0	16.9	14.0	?
152786e	?	?	12.9	?	18.6	?	?

**STRATIGRAPHIC OCCURRENCE.**—Cathedral Mountain Formation.

**LOCALITIES.**—USNM 702, 702b, 702ent, 702un, 703b, 735b.

**DIAGNOSIS.**—*Grandaurispina* (?) with non-capillate exterior and long body spines.

**TYPES.**—Holotype: USNM 152786a. Figured paratypes: USNM 152786a, e, f; 153886g–j. Measured paratypes: USNM 152785a; 152786b, c, e. Unfigured paratypes: USNM 152786b–d.

**COMPARISON.**—This species is unlike any other

assigned to the genus in lacking the capillate exterior of the shell.

**DISCUSSION.**—In external appearance and some details of the interior this species is like *Grandaurispina* but the smooth shell surface is more like *Echinauris*. The cardinal process of the brachial valve has a wide, undeflected median lobe in the myophore, a feature not like typical *Echinauris* but quite characteristic of *Grandaurispina*. The hairlike spines and spine bases are also more suggestive of *Grandaurispina* in their greater abundance on

the brachial valve. For these reasons the species has been tentatively placed with *Grandaurispina* but may ultimately have to be separated from it when more specimens are available.

### *Grandaurispina* species 1

Two specimens from the Road Canyon Formation at USNM 703 and 703c represent an undescribed species. It is characterized by about medium size, and fairly swollen pedicle valve. The posterior is strongly costellate as usual in *Grandaurispina* from the Appel Ranch Member. The ornament or body spines are exceptionally long for the genus, attaining 14 mm at the front. The brachial valve is unknown.

Described specimen: USNM 150007.

### *Grandaurispina* species indeterminate

As with other genera, additional species are represented by specimens in the collection, but the lots are too few or too poorly preserved to justify description. Some of these specimens indicate strata from which this genus has not been reported, showing that the genus has a greater range than indicated by the named species. The presence of these undoubted specimens shows that *Grandaurispina* occurs from the Cathedral Mountain Formation to the Capitan Formation, although it is rare in both of these. They are listed by locality; some are illustrated.

**SPECIES 2** (USNM 707e).—A single, poorly preserved specimen (USNM 155048) is from the Road Canyon Formation.

**SPECIES 3** (USNM 702b).—A poorly preserved specimen (USNM 153861) (Pl. 430: figs. 11–14) shows the presence of this species in the lower Cathedral Mountain Formation.

**SPECIES 4** (USNM 731).—A numerously dimpled brachial valve (USNM 155045) with typical cardinal process proves the presence of *Grandaurispina* in the Hegler Member of the Bell Canyon Formation which has yielded few productids.

**SPECIES 5** (USNM 750a).—Two poorly preserved pedicle valves (USNM 150002a, b) are from the Capitan Formation.

**SPECIES 6** (AMNH 600).—Figured specimens USNM 150015a and b (Pl. 412: figs. 12–18) are two pedicle valves and a fragmentary dorsal valve. The

pedicle valve is elongate, 19 mm in length by 15 mm wide. The body spines are on short, elongate bases and are numerous. Ears not developed. Cherry Canyon Formation (lower Getaway Member).

**SPECIES 7** (USNM 721u).—Figured specimens USNM 155046a, b (Pl. 453: figs. 7–12; Pl. 587: figs. 35–38) represent a small species measuring 21 mm long and 19 mm wide, with a height of 11 mm. The ventral valve is covered by distant small recumbent spines and obscure radial lines. The brachial valve is densely spinose, the spines fine and hairlike. These specimens are important as the earliest undoubted member of the genus. Lower Cathedral Mountain Formation.

### *Holotricharina*, new genus

[Greek *holos* (all) + *trichos* (hair)]

Small to medium size, strongly concavo-convex; quadrate outline; hinge narrower than maximum width; anterior commissure unfolded; ears small. Both valves spiny; spines on pedicle valve of two sizes, large halteroid and thin, delicate ornament spines. Halteroid spines erect attaining length of 20 mm or more, one group on each ear, another at base of umbonal slope and in sparse poorly defined rows parallel to lines of growth. Ornament spines long, slender, delicate, and suberect. Pedicle valve with fine concentric rugae, strongly concentrated on ears but fine and inconspicuous on shell body, otherwise smooth. Brachial valve densely spinose, spines long and hairlike, longest on ears and margins, these directed medially. Surface strongly wrinkled, especially on ears but fairly strong on all parts; wrinkles crossed by fine, delicate capillae.

Pedicle valve interior without ear baffles; muscles lightly impressed; muscle field traversed by long narrow grooves.

Brachial valve interior with small linoproductid cardinal process; posterior platform moderately developed; lateral ridges fairly well developed; ridge supporting cardinal process commonly double where joining posterior platform, tapering to join brevisseptum, which is slender, delicate, and reaching midvalve; anterior slope strongly endospinose.

**TYPE-SPECIES.**—*Holotricharina hirsuta*, new species.

**DIAGNOSIS.**—Linoproductidae related to *Grand-*

*aurispina* but having two sizes of spines on the pedicle valve, noncostellate pedicle valve, and a capillate brachial valve.

COMPARISONS.—This genus is most like *Cancrinella* Fredericks and *Grandaurispina* Muir-Wood and Cooper, but differs from both of them in having two sets of spines adorning the body of the pedicle valve. It will not be confused with *Cancrinella* because the pedicle valve is not capillate or costellate, as is *Cancrinella*, which also has few and scattered spines. *Holotricharina* is closest to *Grandaurispina*, which has two sets of spines, but the arrangement of spines is entirely different in the two genera. In *Grandaurispina* the large halteroid spines are confined to the sides and ears, whereas in *Holotricharina* they are scattered over the body as well. In *Grandaurispina* the ornament or body spines are arranged in quincunx over the body and are short and fairly stout. In *Holotricharina* the ornament or body spines are numerous and of two sizes, one long and hairlike, generally not as long as a thicker set of stout body spines.

DISCUSSION.—Very few brachiopods have different ornament on the two valves. Among the productids a conspicuous example is *Tyloplecta* Muir-Wood and Cooper, in which the pedicle valve has no radial ornament but the brachial valve is capillate. In *Devonoproductus* Stainbrook the pedicle valve is costellate but the brachial valve is concentrically lamellose. This is similar to *Holotricharina*, in which the pedicle valve is marked by concentric wrinkles and concentric growth lines but has no trace of radial lines. The brachial valve, on the other hand, is strongly wrinkled but fine capillae undulate over the wrinkles. In this respect *Holotricharina* also resembles *Grandaurispina*, which has a definitely capillate brachial valve but the pedicle valve may have only obscure capillae or none visible.

Although this genus seldom attains more than a modest size, its halteroid spines attain a length of about an inch. The halteroid spines on the ears generally extend laterally or ventrolaterally but in some specimens this extends at right angles to the ear or almost in any other possible direction. The halteroid spines of the body are generally strongly curved and those near the anterior curve over the margin and overhang the brachial valve.

The fine ornament spines are long and slender and generally hairlike when compared with the

stout halteroid and body spines. The fine ornament spines are also long and curved, but generally they are given off at a much lower angle to the body of the shell than the halteroid spines or large body spines. Spines of both sizes arise from bases, those of the thick body spines are stout and elongated, those of the fine ornament spines, small but also elongated.

The pedicle valve interior of this genus seems to be nearly devoid of definite structures. The specimens of *H. hirsuta*, new species, show no muscle scars and the adductors have no platform. No ear baffles were seen and no marginal or submarginal ridges detected. The only feature that appears is a series of radial ridges, long and slender and suggesting interior spines, that occur in the muscle field. These are developed in many specimens and may be related to the slender body spines which project from the shell also at a low angle.

As usual with all of the productids, the cardinal process of this species is variable. In the adult condition it is typically linoproductid with a wide median lobe, well striated, transversely flanked by smaller lateral lobes, the whole structure in posterior view being distinctly trilobed. Seen from the inside the cardinal process is also trilobed but the lateral lobes are dominant, the median lobe generally small, somewhat elevated but with a deep cleft in the middle. In one adult process the lateral lobes on the posterior face are strongly elevated and inclined medially to overhang and almost enclose the median lobe.

The development of the cardinal process is of interest. It appears as a distinctly bilobed structure with a deep cleft between the lobes, which are joined posteriorly on the posterior margin. In many of the younger specimens a deep pit occurs just anterior to the cardinal process. The pit is gradually filled up as the ridge and platform grow and ultimately disappears. Generally the specimens that had an anterior pit develop a double buttress ridge to the cardinal process.

The size of the shell and condition of the pit anterior to the cardinal process give no idea of the development of the cardinal process. As in most other species a well-developed and adult form of cardinal process may occur in a small shell, and conversely an immature cardinal process appears in some shells judged adult by their size. Both of these conditions occur in specimens of *Holotricharina*.

*hirsuta*. One small specimen has a well-formed adult cardinal process but it has a deep pit anterior to it which is a definite juvenile character. Another specimen is fairly well grown, has no pit, but has a small bilobed cardinal process in which the lobes are not connected.

As noted above, the development of the structures accessory to the cardinal process are also variable, such as the lateral ridges, and the buttress ridge. The lateral ridges are thick and strong in some specimens; each commonly joins a wrinkle across the ear to form a small ear baffle but many specimens with weakly developed lateral ridges have no baffle across the ears.

In young specimens the brevisseptum is a discrete plate arising anterior to the pit under the cardinal process, extending nearly to midvalve and elevated anteriorly. In growth a low ridge forms on each side of the pit and converges to the proximal end of the brevisseptum, finally uniting with it. Thickening continues until the pit is obliterated and a ridge, broad near the cardinal process but tapering anteriorly, is formed. In adults the passage from brevisseptum, a primary structure, to buttress ridge, a secondary structure, is difficult to discern, especially in silicified specimens.

The irregular wrinkling on the exterior of the brachial valve makes the interior surface also irregular. The pits of the exterior form bosses and swellings on the interior, especially where the wrinkling is strongest on the ears and the trail slope.

These areas are also the sites of development of endospines. These, as in *Grandaurispina*, are not distributed evenly over the surface or arranged in rows, as in some genera, but appear as groups of two or more usually concentrated on a swelling produced by a swale on the exterior. This arrangement gives a patchy appearance to the trail slope. Brachial ridges were not seen in any of the specimens studied.

**GROWTH.**—Three immature specimens of this genus were recovered from the residues. These show clearly an early differentiation of spines into halteroid and fine ornament spines. The latter, however, in the young are not strongly differentiated and must have served as halteroid spines until early adulthood. Evidence for ring attachment appears in one specimen but the ring is not complete.

### *Holotricharina hirsuta*, new species

PLATE 444: FIGURES 1–49; PLATE 445: FIGURES 9–15; PLATE 446: FIGURES 42–45

Small to medium size, variable in outline from slightly transversely subrectangular to subquadrate or subcircular; sides nearly straight to gently rounded; anterior margin broadly rounded; anterior commissure unfolded; hinge narrower than midwidth; ears small, slightly obtuse. Halteroid spines long and stout, attaining length of 25 mm. Ornament spines long and slender, usually numer-

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702c							
149896a	14.0	11.0	25.0	14.0	15.9	8.2	3.7
(holotype)							
149896b	14.8	11.1	28.0	13.2	15.8	8.7	4.9
149896c	12.9	11.0	23.0	12.4	15.5	6.8	3.8
149896d	11.1	9.0	21.0	9.7	14.0	6.1	3.0
149896e	11.6	9.6	20.0	14.6	14.3	6.8	3.4
149896f	11.8	9.1	23.0	12.5	14.0	7.3	3.7
149896g	10.2	8.8	18.0	8.2	12.2	5.6	3.1
149896h	10.1	9.0	18.0	9.6	12.3	5.4	3.2
149896i	10.2	8.3	18.5	11.9	11.5	6.3	2.5
149896j	9.9	8.4	15.0	9.0	11.5?	4.4	2.5
149896k	9.3	8.0	15.0	7.6	10.5	4.4	2.8
149896l	15.8	11.5	30.5	13.1	16.2	9.8	5.5
149896m	13.5	9.6	26.0	12.6	15.1	8.0	4.0

ous but variable in arrangement and number. Both valves wrinkled, strongest wrinkles crowded at ears and on sides.

Pedicle valve fairly evenly and strongly convex in lateral profile but umbonal region narrowly curved; anterior profile a high dome with precipitous sides. Beak small; umbonal region swollen, protruding moderately posterior to posterior margin. Median region strongly swollen. Sulcus seldom developed.

Brachial valve deeply concave and with steep slopes on sides and anterior. Ears slightly developed. Surface closely wrinkled and covered by veritable forest of spines.

Interior as described for genus.

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain and Road Canyon formations.

LOCALITIES.—Cathedral Mountain: USNM 726o. Road Canyon: AMNH 507; USNM 702c, 703, 703a, 703c, 703d, 721o, 721r, 721s.

TYPES.—Holotype: USNM 149896a. Figured paratypes: USNM 149894a, b; 149896c; 153899a-s; 153914. Measured paratypes: USNM 149896b-m. Unfigured paratypes: USNM 149896b, d-m.

DIAGNOSIS.—Medium-sized *Holotricharina* with numerous spines on the body and long halteroid spines.

COMPARISON.—This species is distinguished from *H. sparsa*, new species, the only other species, in its more numerous spines, longer and stronger halteroid spines on the flanks, and less deep brachial valve. The species is common at USNM 702c but it is rare elsewhere.

### *Holotricharina sparsa*, new species

PLATE 445: FIGURES 16-30

Fairly large for genus, subrectangular in outline; hinge width slightly less than midwidth; sides nearly straight; anterior margin broadly rounded. Ears small, slightly obtuse. Pedicle valve with strong irregular and laterally interrupted wrinkles concentrated on ears, flanks, and trail, otherwise marked only by concentric lines of growth; brachial valve with strong wrinkles covering entire surface but most prominent on ears; entire surface covered by obscure capillae, strongest in swales between wrinkles. Halteroid spines stout, few on ears and at base of umbonal slopes, and few scattered over body of shell. Fine body ornament spines fairly numerous, strongly recumbent.

Pedicle valve strongly convex in lateral profile but most rounded in umbonal region; anterior profile high dome with steep sides. Umbonal region small, not protruding strongly posterior to posterior margin. Median region swollen. Sulcus originating on venter as slight flattening or just noticeable depression on trail tending to obsolescence at front margin; flanks well rounded and steep.

Brachial valve deeply concave, deepest at mid-valve and with steep lateral and anterior margins. Ears small, narrowly concave, and demarcated by low, oblique ridge. Umbonal region deeply depressed.

Pedicle valve interior with internal ridges; sides and anterior slopes granulose. Ears with several large spine openings.

Brachial valve interior with small cardinal process on prominent posterior platform; lateral ridges strong in adults; cardinal process with anterior dimple in young. Cardinal process buttress ridge weakly developed. Brevisseptum strong. Endospines strong and long, forming short patch anterior to brevisseptum; endospines in groups of 2 or 3, occasionally 2-pronged. Trail slope long and granulose.

MEASUREMENTS (in mm).—From locality USNM 707e, specimen 149904a (holotype): length 13.5, brachial valve length 10.4, surface length 26.0, hinge width 15.2, midwidth 16.4; height 8.2, thickness 3.5.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 707e, 710z, 719x, 720d, 721j, 724a, 724b, 724j, 726d, 732j, 736x.

DIAGNOSIS.—*Holotricharina* with few halteroid spines on the body; fine body spines, few and scattered.

TYPES.—Holotype: USNM 149904a. Figured paratype: USNM 149904b.

COMPARISONS.—This species is readily distinguished from *H. hirsuta*, new species, by the less numerous halteroid spines appearing on the body of the shell, by its more transverse dimensions, and the stronger wrinkling of both valves.

DISCUSSION.—*Holotricharina sparsa* is a very rare species, only 16 lots having been recovered from the residues of the Road Canyon Formation. These indicate a species of considerable variability in its spine development. Two specimens are distinctly more spinose than the others, but the halteroid



spines are distinctly few on the body of the shell. The increase is in the ornament spines.

The collection includes two brachial valve interiors, one young one and the other an exquisitely preserved adult. The young one shows a pit anterior to the cardinal process and the beginnings of the buttress ridge on each side of it. The adult has a fine development of the endospines and a long trail anterior to them.

### *Holotricharina?* species 1

PLATE 445: FIGURES 31, 32

Large for genus, subcircular in outline but length slightly greater than width. Sides rounded; maximum width at midvalve; hinge narrow and forming small acute ears separated by anterior notch. Spines consisting of three sizes; tuft of thick halteroid spines overhanging each ear, attaining length of at least 12 mm, constituting longest and thickest spines on shell; body spines of two thicknesses, one fine and delicate, measuring about 7.5 mm; and thicker spines, intermediate in thickness between finest ones and lateral halteroid spines, attaining length of 11 mm. Spine bases low and short. Shell surface marked by concentric wrinkles but without radial ornament.

Brachial valve unknown.

Figured specimen: USNM 152787.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITY.—USNM 703a.

DIAGNOSIS.—The largest *Holotricharina* known.

### Genus *Yakovlevia* Fredericks, 1925

*Yakovlevia* Fredericks, 1925a:7.—Kotlyar, 1961:459.—Muir-Wood and Cooper, 1960:323.—Williams et al., 1965:H506.  
*Muirwoodia* Licharew, 1947:187.—Muir-Wood and Cooper, 1960:322.

Variable usually about medium size, transversely rectangular in outline; hinge usually wider than midwidth; ears usually prominent. Visceral cavity thin. Anterior commissure uniplicate, fold of brachial valve generally strong. Visceral disc region gently concavo-convex; geniculation abrupt and strong; trail generally long. Surface of both valves capillate to costellate. Pedicle valve with long, thick halteroid spines; one on each ear; one on trail on

each side of sulcus just anterior to venter; row of fine oblique spines just anterior to posterior margin; and occasional scattered spines on visceral disc, venter, and trail. Brachial valve without spines.

Pedicle valve interior usually with well-developed ginglymus; muscle field large, transversely cordate in outline, diductor muscles large and flabellate, separated anteriorly by thick platform on posterior, bearing hook-shaped anterior adductor scar; posterior adductors outside and posterior to anterior pair, large and dendritic. Areas outside muscle field granulose.

Brachial valve interior with poorly developed or variably developed lateral ridges; posterior platform small, bearing small, low, linoproductid cardinal process; cardinal process supported anteriorly by callus extending between adductors to brevisseptum; adductors without platform, consisting of two pairs, an inner narrowly elongate pair and a large dendritic pair lying posterolaterally to inner pair. Brachial ridges well-developed, extending directly laterally with large loop. Brevisseptum strong, elevated to crest anteriorly. Endospines small, in row at place of geniculation; trail slope strongly granulose.

TYPE-SPECIES.—*Chonetes* (*Yakovlevia*) *kaluzinensis* Fredericks (1925a:7, pl. 2: figs. 64-66).

DIAGNOSIS.—Capillate to costellate, narrowly concavo-convex Linoproductidae with four basic halteroid spines and a sharp anterior geniculation.

COMPARISON.—The chonetiform flat valves of the young of *Yakovlevia*, the strong and narrow geniculation of the pedicle valve, and the pattern of spines on this genus are distinctive. The finely capillate to costellate exterior and the cardinal process clearly relate this genus to the Linoproductidae. No other genus of productids (except *Kutorginella*) is known with the basic pattern of four large halteroid spines; two on the ears and two on the trail. The combination of characters is distinctive.

NOMENCLATURE.—*Yakovlevia* was proposed by Fredericks in 1925, who thought that the genus was related to *Chonetes* but that it also had productid characters in its external form. The supposed presence of an interarea and spines along the posterior margin suggested the relationship to *Chonetes*. Although Fredericks mentioned clearly the similarity of his genus to *Productus mammatus* Keyserling, his description was not sufficient and his specimens too poor for Licharew (1947) to satisfy himself on

this point. Licharew, therefore, created the genus *Muirwoodia* in 1947. Muir-Wood and Cooper (1960) interpreted *Yakovlevia* as a productid but regarded it as different from *Muirwoodia*.

That *Muirwoodia* and *Yakovlevia* are synonyms now becomes clear through the work of Kotlyar (1961) who revised *Yakovlevia* on the basis of new collections. He shows that the cardinal area (= interarea) of Fredericks is in reality "none other than a thickened hinge margin which B. K. Licharew calls a 'marginal area.' " It is the feature, present on many of our Glass Mountains species, that we prefer to call a ginglymus. Kotlyar obtained brachial valves of *Yakovlevia* as well as pedicle valves; these are clearly productid and are identical to interiors hitherto referred to *Muirwoodia*. We are convinced that Kotlyar has fully settled the question of the status of *Yakovlevia* as senior synonym of *Muirwoodia*.

DISCUSSION.—The exterior of *Yakovlevia* is very distinctive and is not easily confused with other genera. Its finely costellate or capillate ornament and the sharp geniculation of the anterior are important features. The most significant character of the genus, however, is the arrangement of its spines, which are confined to the pedicle valve and are designed for living free on the sea bottom.

The basic pattern of spines in *Yakovlevia* consists of four halteroid spines of large size and considerable length. Two of the spines are posteriorly located while the other two are anterior. The posterior spines are situated on the ears, one at the angular extremity of each ear. These spines extend at various angles to the posterior margin and are generally strongly oblique, although the angle varies from nearly parallel to the posterior margin to 45°. Ear spines 40 mm long have been measured.

Two large halteroid spines on the trail complete the basic pattern. These are on each side of the sulcus a short distance anterior to the angle of geniculation. These spines have been measured at 48 mm in length. The four spines make a broad base upon which the shell rested on the surface of the mud or sand where it lived. Aberrations appear in the development of these spines because in some specimens three spines may be developed on the trail and an additional spine may appear on the ear angles. Occasionally a spine may be lacking from one of the ears or trail.

In addition to the four basic spines smaller spines

appear in a row just anterior to the posterior margin. These extend laterally at a low angle and suggest some chonetid spines. Indeed the young of this genus have been confused with chonetids and Fredericks (1925) referred his pedicle valve to *Chonetes*. Other small spines appear anywhere on the visceral disc, or venter, but generally not on the trail anterior to the main spines. Broken spines or sealed bases commonly appear on each side of the sulcus posterior to the main spines of the trail. These are evidently halteroid spines sent out at a younger stage and then abandoned.

Features of considerable interest appear on the interior of *Yakovlevia*. The ginglymus is a short flattened area extending laterally from the beak but never for the entire hinge width. It strongly suggests an incipient interarea, but its occurrence is not uniform; some specimens are provided with it but in others it is not present or not clear. In addition to the ginglymus, the posterior or hinge region of the pedicle valve is marked by a linear flattened area well demarcated from the lateral portions and extending the full width of the hinge and into the ears. This flattened band is irregularly pitted, the pits corresponding to nodes or granules along the posterior margin of the opposite valve. These areas of pits and nodes are thought to be helpful in articulation of these wide shells.

The most conspicuous feature of the pedicle valve of *Yakovlevia* is the muscle field, which is large and generally widely heart-shaped. The diductor scars are triangular and anteriorly spreading. Anteriorly and laterally they are generally surrounded by a shell thickening that makes them appear deeply impressed. The anteromedial ends of the diductor scars are separated by a thick, narrow platform that decreases in height posteriorly to become flush with the valve floor near the middle of the muscle field. The anterior adductor scars are located on the posterior or lower part of this platform. The anterior adductor scars are long and slender, looped posteriorly at the anterior end and in the opposite direction at the other end. Their surface is smooth. In some, the loops are either not developed or are not clear and then each scar appears to consist of two tear-shaped impressions joined at a slight angle at their posterior extremities. The form of these muscle scars is like that in *Paucispinifera* and other genera.

Dentritic posterior adductor scars appear pos-

terolateral to, and surrounding, the posterior of the anterior adductors. These are large and form an elliptical patch in midvalve anterior to the beak. These dendritic scars are separated from the diductor scars by a layer of callus that advances anteriorly over the posterior of the diductors as they grow anteriorly. The thickening around the anterior and sides of the muscle field is, in many specimens, considerable, and is strongly elevated. The inside of the trail surface is strongly granulose.

Many specimens of the pedicle valve of *Yakovlevia* show that the four large basic halteroid spines were open into the valve. These openings appear as round holes at the ears and on the inside of the trail. The inner openings are not produced into tubes as in some members of the Marginiferidae or Paucispiniferinae. That these spines did not stay open indefinitely is clearly shown by many specimens in which callus has been deposited in and around the inner opening. In some the openings have been altered to slits and in others they are much reduced. The sealed spine opening appears as a smooth round patch, conspicuous among the coarse granules of the trail.

Most species of *Yakovlevia* are satisfactory for study because many of the interior details have been exceptionally well recorded in shell tissue. Lateral ridges are not uniformly developed and generally are not clearly visible. The posterior margin is flattened and usually demarcated by a change in slope or by a small ridge that extends at a slight angle toward each ear. These ridges appear to be the lateral ridges and they define areas marked by small nodes that correspond to and articulate with the flattened region of the pedicle valve just anterior to the ginglymus, or posterior margin. It seems clear that these flattened areas in both valves are surfaces of articulation and probably of movement.

The cardinal process is typically linoproductid and lies on a small smooth posterior platform. In old specimens the cardinal process is rotated to a position oblique to the posterior margin but this rotation is not as strong as in *Grandaurispina*. The cardinal process is variable in size and in lobe development but appears more uniform than in many other genera.

The shell surface just anterior to the cardinal process is a place of callus deposition. In some linoproductids this is the site of a ridge extended an-

teriorly from the cardinal process. In *Yakovlevia* such a ridge is not developed and the callus is not laid down in a uniform pattern. In most specimens it strengthens the region around the cardinal process and then extends anteriorly toward the muscle field, where it may send obscure or thick fingers between the adductor muscles and around their outer margin for a short distance. Generally this thickening does not extend to the brevisseptum and therefore does not form a ridge continuous with it, as in other linoproductids.

Ear baffles and marginal ridges are not well developed in this genus. Low ridges across the ears have been seen in a few specimens but are rare. Endospines are numerous but generally small. Large ones appear near the place where the visceral disc and trail separate, but these taper in size to the status of granules on the anterior trail slope. The brachial ridges are well developed in *Yakovlevia* and extend directly laterally from the muscle field to make a narrow loop on the anterolateral extremity of the visceral disc. This loop is usually well thickened and bounded on the exterior by a narrow ridge. Inside the loop an oblique ridge divides the lateral loop.

The adductor field is fairly large and is occupied by an inner and an outer pair of scars. The inner scars are narrowly elongate and similar in form to those of the pedicle valve. The outer scars are intricately dendritic and large.

### *Yakovlevia anterospinosa*, new species

PLATE 244: FIGURES 23-27

Medium size for genus, transversely rectangular in outline, hinge forming widest part, ears acutely angular. Sides sloping strongly medially; anterior margin deeply indented. Surface marked by fine, threadlike costellae, about 12 per 5 mm at front. Spines as described for genus but with row along posterior margin and occasional scattered ones on trail. Two large trail spines located well forward on anterolateral side of flanks.

Pedicle valve strongly convex in lateral profile, maximum convexity near middle of curve; anterior profile broad, deeply indented dome with steep sides; sulcus originating near place of geniculation, broadly V-shaped, and deep.

Brachial valve deeply concave with broadly con-

cave umbonal region; deepest opposite flanks of pedicle valve; fold fairly strong, visible, only on geniculated trail.

Pedicle valve interior with thickened adductor area. Brachial valve with faint marginal rim, narrow brachial ridges and small cardinal process.

MEASUREMENTS (in mm).—From locality USNM 732j, specimen 154519a (holotype): length 21.5, brachial valve length 20.0, midwidth 32.3, hinge width 38.2, height 15.0, thickness 3.5.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITY.—USNM 732j.

DIAGNOSIS.—Medium-sized, finely costellate *Yakovlevia* with deep sulcus, maximum height at midvalve.

TYPES.—Holotype: USNM 154519a. Figured paratype: USNM 154519b. Unfigured paratype: USNM 154519c.

COMPARISON AND DISCUSSION.—*Yakovlevia anteropspinosa* is similar to *Y. costellata*, *Y. hessorum*, *Y. indentata*, and *Y. sulcata*, all new species. From the first it differs in its greater convexity in lateral profile, less wide sulcus, more angular ears, and the sulcus originating farther anteriorly. It is smaller than *Y. hessorum* and its anterior two spines are farther forward on the trail than those of the Willis Ranch Member species. Furthermore, its spines are finer and it is more deeply sulcate than *Y. hessorum*. It is not strongly folded like *T. indentata* because it is not so wide and its sulcus does not originate so far posteriorly. It is larger than *Y. sulcata* and not so narrowly rectangular as that species. It does not have the strongly thickened interior of the other Road Canyon species. *Y. anteropspinosa* is very rare in the Road Canyon Formation.

### *Yakovlevia costellata*, new species

PLATE 469: FIGURES 15–27

Large for genus, transversely rectangular in outline, hinge forming widest part; ears prominent, forming angle of about 60°. Sides sloping medially; anterior margin broadly rounded, gently indented. Surface costellate, with seven costellae in 5 mm. Six spines along hinge including large terminal spine. Halteroid spines as described for genus.

Pedicle valve lateral profile unevenly convex, posterior gently convex but anterior half more

strongly convex; venter broadly rounded; angle of geniculation about 85°. Anterior profile broadly convex and fairly deeply indented medially, sides sloping fairly steeply. Umbonal region slightly swollen, with short gentle slopes to lateral extremities. Visceral disc region fairly strongly swollen. Sulcus originating near middle of visceral disc, fairly deep but wide. Flanks bounding sulcus strongly swollen; trail slope steep. Two large halteroid spines just posterior to margin. Ears rounded in section.

Brachial valve fairly deep, greatest depth in troughs on each side of low, narrowly rounded fold. Ears flattened and defined by gentle oblique fold of shell in ventrad direction. Sides and anterior low but steep.

Pedicle valve interior with broad, deeply pitted band thickened along posterior margin; muscle field large, not strongly impressed. Adductor platform low and narrow. Surfaces anterior and lateral to muscle field granulose or pitted.

Brachial valve interior with broad granulose posterior band bounded by poorly defined lateral ridges; no ear baffles; posterior platform moderately thickened; cardinal process small; adductor field small, brevisseptum strong and elevated distally. Brachial ridges well developed; region between brachial ridges and brevisseptum greatly thickened. Endospines thick and long.

MEASUREMENTS (in mm).—Thickness of holotype 6.0; of others, unmeasurable.

	brach- ial valve length	sur- face length	hinge width	mid- width	height
USNM 728					
151502a	20.0	17.7	35.0	34.8	29.4
(holotype)					
151502b	19.6	?	31.5	38.9	29.7
151502c	?	18.0	?	40.0	31.1

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member).

LOCALITY.—AMNH 512 = USNM 728.

DIAGNOSIS.—Widely transverse, strongly costellate *Yakovlevia*.

TYPES.—Holotype: USNM 151502a. Figured paratypes: USNM 151502b–d. Measured paratypes: USNM 151502b, c.

COMPARISONS.—This species should be compared



to those species of intermediate size: *Y. transversa* (Cooper) and *Y. sulcata*, *Y. intermedia*, and *Y. immatura*, all new species. It differs strikingly from *Y. sulcata* and *Y. transversa* in having much more rounded contours, less angular geniculation, stronger costellae than *Y. sulcata*, and a wider, and less pronounced sulcus than *Y. transversa*.

*Yakovlevia indentata*, new species, is somewhat more strongly costate and has a longer trail than *Y. costellata*. Furthermore, the sulcus of the upper Word species is deeper and more pronounced, the flanks fuller and the interior details of both valves much less strongly developed.

*Yakovlevia costellata* is smaller and more strongly costellate than *Y. intermedia*. The sulcus of the latter is much deeper than that of the Guadalupe Mountains form and the trail is far longer. The flat form, short trail, and finer costellae separate *Y. immatura* and *Y. costellata*. *Yakovlevia costellata* is rare in the Getaway Member of the Cherry Canyon Formation, only 9 specimens having been found in the residues in the USNM and Columbia University.

*Yakovlevia hessorum*, new species

PLATE 434: FIGURES 1-8; PLATE 452: FIGURES 29-34; PLATE 473: FIGURES 1-17; PLATE 474: FIGURES 1-24

*Productus multistriatus* R. E. King (not Meek), 1931:71, pl. 13: figs. 1, 2 [not 3, = *Y. deminutiva* (Cloud)].

*Muirwoodia* cf. *M. multicostata* Muir-Wood Cooper (not Meek), 1960:322, pl. 120: figs. 1-11.

Large, transversely rectangular in outline; hinge forming widest part. Sides sloping medially; anterior margin broadly rounded and indented medially. Ears large, acutely angular. Surface capillate, 2 or 3 per mm on trail of adults. Halteroid spines large and long, attaining length of nearly two inches. Posterior margin with row of 7 or 8 small spines in addition to large ear spines.

Pedicle valve narrowly and unevenly convex in lateral profile, greatest curvature at venter, visceral disc region very gently convex, trail slightly more convex than visceral disc. Anterior profile broadly domed and indented medially by sulcus, sides sloping steeply. Beak small; umbo gently swollen and merging into flatly convex visceral disc, protruding slightly posterior to posterior margin. Angle of geniculation near 60°. Sulcus originating 8-10 mm anterior to beak, deepening anteriorly, but

generally narrow and shallow. Flanks bounding sulcus moderately swollen. Trail long and steep, gently curved to nearly flat in profile; umbonal slopes short, moderately steep. Ears narrowly rounded in section, forming angle about 55°.

Brachial valve with concave umbonal region; visceral region gently concave and marked medially by narrow, low, carinate fold originating just anterior to umbonal depression. Areas bounding fold forming deepest parts of valve; ears gently concave, defined by low deflection of valve; sides and anterior steep; angle of geniculation slightly less than right angle (about 83°).

Pedicle valve interior with wide muscle field deeply inserted and bounded by thick rims laterally; adductor platform thick and wide.

Brachial valve interior with poorly developed lateral ridges; cardinal process small and with poorly developed posterior platform; adductor impressions lightly impressed, outer dendritic scars large; brachial ridges well formed.

MEASUREMENTS (in mm).—For specimen USNM 151486v, brachial valve length 25.3 and thickness 10.6; for others, these were unmeasurable.

	length	surface length	hinge width	mid-width	height
USNM 706e					
151486a	31.8	50.0	55.6	40.8	18.3
151486b	28.8	54.0	50.6	38.3	19.7
151486c	26.0	47.0?	46.4	35.7	16.4
151486d	25.0	40.0	47.8	34.2	14.4
151486e	23.7	38.5	43.0	31.9	13.0
151486f	23.4	44.0	38.8	30.9	15.4
151486g	21.0	31.0	41.8?	30.7	10.4
151486h	24.7	42.0	40.9	31.0	15.4
151486i	22.8	33.0	41.8	30.0	10.5
151486j	23.0	32.0	44.7	31.0	10.0
151486k	22.0	28.0	41.4	32.2	7.3
151486l	25.5	37.0	46.4	33.4	10.6
151486m	11.7	14.0	22.7	17.9	3.6
151486v	31.0	51.0?	48.2	35.0	19.0
153980h	26.6	49.0	44.0	33.0	18.2
(holotype)					

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank and Willis Ranch members).

LOCALITIES.—Word: USNM 731m. China Tank: USNM 706z, 713. Willis Ranch: AMNH 505; USNM 706, 706e, 723t, 724u.

DIAGNOSIS.—Large, wide-hinged *Yakovlevia* with flattened visceral disc region.

TYPES.—Holotype: USNM 153980h. Figured



paratypes: USNM 124051b, c, e; 151485a-c; 151486k, n, p-v; 151860; 153979a-e, g, h; 153980a-g, j; 154037a, b; 154102. Measured paratypes: USNM 151486a-m, v. Unfigured paratypes: USNM 124051a, d; 151486a-j, l, m, o; 153979f; 153980h, i.

COMPARISON.—This species is likely to be confused with only three other described species: *Y. multistriata* (Meek), *Y. intermedia*, new species, and *Y. indentata*, new species. King identified the specimens from the Willis Ranch Member as Meek's Nevada species. *Y. multistriata*, and this name has generally been applied indiscriminately to most large specimens of *Yakovlevia* from the American Permian. Comparison of the Word species with the type specimen and other specimens from the Phosphoria Formation of Nevada shows these two to be quite unlike. The length and width of the two species is similar but the measurements of surface length indicate that *Y. multistriata* has a much longer trail than that seen in any specimens of *Y. hessorum*. The trail of *Y. multistriata*, as shown by the type specimen, may attain half the surface length, and although the development of the sulcus of the two species is quite similar, the visceral and umbonal regions of *Y. multistriata* are much more inflated than the same regions in *Y. hessorum*. The interior details of these two species is as unlike as the exterior, the brachial valve having a strong rim around the visceral region and all of the structures being heavily calcified.

*Yakovlevia hessorum* resembles *Y. intermedia* at superficial glance, but in detail the two are quite unlike. The visceral and umbonal regions of the China Tank species is nearly flat, while that of *Y. hessorum* is moderately swollen. The sulcus of *Y. intermedia* is somewhat stronger and deeper than that of the Willis Ranch species and this combined with the strongly rounded flanks and flat visceral disc give *Y. intermedia* a more narrowly convex profile. The few specimens of the latter species preserving parts of the halteroid spines indicate that these spines on *Y. hessorum* are much thicker and stronger.

*Yakovlevia indentata* approaches *Y. hessorum* in size but is more strongly costellate, has a deeper sulcus, and more narrowly rounded flanks bounding the sulcus. Inside the brachial valve the interior structures of the Appel Ranch species are considerably more thickened and the median depression much deeper.

Although *Y. hessorum* is fairly common at USNM 706e in the upper part of the Willis Ranch Member, it is, nevertheless, difficult to obtain undamaged specimens. This locality seems to have been the site of a death assemblage in which currents piled together many different species. The long and delicate halteroid spines of this species did not survive the washing about. It is doubtful that any specimen in the collection, even among the few most complete ones, actually preserves the full length of the spines. In the majority of specimens most of the early delicate body spines are recorded only as small holes. Most of the spines on the row along the posterior margin also were lost before burial.

GROWTH.—A number of immature specimens of this species were recovered in the residues from USNM 706e, making it possible to obtain a good idea of the development of the species. The course of growth shown by these specimens probably is a fair example of the growth of other species as well. In young stages *Yakovlevia* is reminiscent of some chonetids, because of the oblique spines located just anterior to the posterior margin. The submarginal position of these spines is a ready distinction from the chonetids, but it is not always apparent unless the specimens are studied with care.

The smallest specimen, a pedicle valve (USNM 151485a), measures 3 mm in length and 5 mm in width at the hinge, which is considerably extended. This specimen has four spines just anterior to the posterior margin. Two are stubs, or bases, on the umbo and the next adjacent ones lie at the base of the umbonal slope but extend directly posterior and then hook inward. These and the umbonal spines undoubtedly represent the remnants of an attachment ring. Outside of these and just anterior to the posterior margin two spines extend laterally at a very low angle to the posterior margin. These are chonetid in aspect and the outer one measures a little more than 3 mm, which is equal to the valve length. Continued growth does not materially change the outline of the young *Yakovlevia*. As growth continues, however, the umbonal and median regions become more swollen and the spines seem to migrate closer to the posterior margin, but this is an illusion. Continued widening and growth sees the addition of more spines just anterior to the posterior margin. A specimen 8 mm long has four

spines on each side of the beak. Five spines were counted on a specimen 12 mm long.

More adult characters appear at the attainment of 20 mm of length. Specimen USNM 151486-I indicates the beginning of geniculation and the development of the two anterior trail spines. Some specimens of about this size appear to have put these spines out tentatively, because they were abandoned and another pair tried after a short interval. Specimen USNM 151486q, (21 mm long) has two sets of small spines and specimen USNM 151486r (about 24 mm long) has three sets of them, two small and delicate but the third, large and fully adult. Specimen USNM 151486t (23 mm long) has seven spines along the hinge, the last two extending at a higher angle than the others and representing the large halteroid spine of the ear. In this case two of these were sent out, the first two large marginal spines, but the last, which is on the ear extremity, being the main lateral halteroid spine. At this length this particular specimen had already twice tried two generations of halteroid spines, but their bases are delicate and the spines lost. Specimens in the length range of 21 to 25 mm develop the full adult characters and sent out the "permanent" set of anterior halteroid spines. After the appearance of these spines the only change is lengthening of the trail and a consequent slight proportional change of the ratio of length to width. The sulcus originates at about 10 mm of length but becomes prominent with the inception of geniculation.

Young brachial valves are rare; none is as small as the pedicle valve described above, consequently no significant changes were noted in the development of this valve.

The species is named for Mr. and Mrs. Leonard Hess in appreciation of their continued interest in our field work and their cordial welcome to us at the Hess Ranch.

*Yakovlevia immatura*, new species

PLATE 469: FIGURES 1-11

Large, not strongly geniculated, transverse and subrectangular in outline, hinge forming widest part. Ears large, acute. Sides sloping medially. Anterior margin strongly and widely indented. Surface costellate, 9 costellae in 5 mm at anterior of shell. Spines delicate, arranged as in generic description.

Pedicle valve with chonetid appearance, flatly convex in lateral profile but with anterior sharply bent at obtuse angle (near 120°), but trail short. Anterior profile wide, low dome with median depression and long, gently sloping sides. Umbonal region slightly swollen; umbonal slopes low, long, and gentle. Sulcus prominent, originating on umbonal region, widening and deepening anteriorly. Flanks bounding sulcus moderately swollen. Trail short but steep. Cardinal extremities forming angle near 60°.

Brachial valve moderately concave and with prominent, narrow fold originating just anterior to umbonal depression. Areas bounding fold forming deepest part of valve; ears gently concave, formed by broad flattening of posterolateral extremities; sides and anterior short and steep.

Pedicle valve interior with broad flattened band of pitted shell along posterior margin. Muscle field small, not greatly thickened around margins. Adductor platform grooved anteriorly but low and not greatly thickened. Areas bounding muscle field strongly granulose.

Brachial valve interior with well-developed granulose band; thick brevisseptum set in trough caused by dorsal fold; adductor field slightly thickened. Endospines long and stout, forming row over short trail.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 703d							
151504a	18.3	16.8	24.0	38.4	30.0	6.8	2.2
(holotype)							
151504b	19.4	17.8	26.0	39.5	33.0	7.0	2.7
151504c	19.1	17.8	23.0	34.8?	29.0	6.0	1.7
151504d	18.7	?	23.0	36.8	30.0	6.0	?
151504f	13.6	?	15.0	27.8	23.0	?	?

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—AMNH 503; USNM 703c, 703d.

DIAGNOSIS.—Large, flattened transverse *Yakovlevia* having a short trail and delicate spines.

TYPES.—Holotype: USNM 151504a. Figured paratypes: USNM 151504b, d, g. Measured paratypes: USNM 151504b–d, f. Unfigured paratypes: USNM 151504c, e, f.

COMPARISONS.—This species is unique among American species of *Yakovlevia* because of its short trail, flat and generally chonetid form. If it were not for the fact that the 13 specimens available have nearly the same measurements, we would have been inclined to regard these specimens as not fully grown. In both exterior and interior details they show evidence of being adults. The large halteroid spines of the trail are indicated about halfway down the short trail. The older of the two brachial valve interiors is strongly thickened indicating old age, and its trail is short in keeping with the pedicle valves. This species, therefore, by virtue of its chonetid form is readily distinguished from other American species.

*Yakovlevia indentata*, new species

PLATE 470: FIGURES 1–28; PLATE 471: FIGURES 18–24

*Productus guadalupensis* R. E. King (not Girty), 1931:61, pl. 10: figs. 9a–c, 10a–c (not 11).

Medium size for genus; transversely rectangular outline, hinge forming widest part. Ears large, acute, forming angle of about 60°. Sides sloping medially; anterior margin broadly indented. Surface costellate,

6 or 7 costellae per 5 mm on trail just anterior to venter. Spines slender, arranged as described for genus.

Pedicle valve strongly but unevenly convex in lateral profile, posterior half gently convex but anterior half moderately convex; venter narrowly rounded, trail long and gently convex. Anterior profile forming two mounds bounding deep, broadly V-shaped depression and sides sloping steeply. Umbonal region gently inflated but with short and fairly steep umbonal region, deep and wide; flanks bounding sulcus somewhat narrowly inflated and steep-sided. Trail long and fairly steep. Ears narrowly convex, almost carinate.

Brachial valve with deep umbonal depression; fold strong, broad, inverted V dividing two deep, troughlike areas forming most concave or deepest parts. Ears deeply concave demarcated by broad oblique undulation of surface; sides steep but anterior trail somewhat less steep.

Pedicle valve interior with broad, well-differentiated, flat, pitted band on anterior side of posterior margin. Muscle field narrowly triangular, deeply inserted, with rounded triangular diductors separated by thick adductor platform. Inner surface strongly granulose or pitted.

Brachial valve interior strongly thickened; posterior platform fairly large; lateral ridges anteriorly bounding granulose posterior band. Anterior adductor pair of scars strongly differentiated and thickened, elevated above outer scars lying in pit. Brachial ridges thickened. Brevisseptum strong and high, lying in trough formed by exterior fold. Endospines thick and long forming fringe at angle of geniculation.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 715i							
151513a	23.7	?	42.0	40.0	32.3	14.3	?
151513b	21.6?	18.0	40.0	41.0	34.0?	16.0?	5.6
151513c	20.0	?	32.0	42.2	31.6	13.5	?
151513d	?	20.0	?	37.6	27.0	?	?
151513e	18.8	16.0	30.0	36.2	29.2	12.8?	6.0
(holotype)							
151513f	16.5	?	26.0	34.9	28.7	?	?

STRATIGRAPHIC OCCURRENCE.—Word Formation (Appel Ranch Member).

LOCALITIES.—USNM 715i, 719z, 722t, 727j; YPM 246.

DIAGNOSIS.—Strongly costellate *Yakovlevia* with deep sulcus and widely indented anterior margin.

TYPES.—Holotype: USNM 151513e. Figured paratypes: USNM 151513c, d, f; 154038; 154039a, b; 154040a, b. Measured paratypes: USNM 151513a–d, f. Unfigured paratypes: USNM 151513a, b.

COMPARISON.—This species is similar in form and outline to *Y. hessorum* and *Y. intermedia*, both new. It is compared with the former species under that heading. It differs from *Y. intermedia* in having stronger costellae, a more inflated visceral disc region, and less angular lateral profile. The interiors of the two differ in the greater thickening of the structures of *Y. indentata*.

*Yalovlevia indentata* is an uncommon species in the Appel Ranch Member of the Word Formation. King (R. E., 1931:67) confused specimens of this species with Girty's *Productus guadalupensis*, which is smaller, differently ornamented, and has an entirely different arrangement of the spines. The latter species may well belong to the genus *Paucispinifera* rather than *Yakovlevia*, although we have treated it as an undescribed and incompletely understood species of *Yakovlevia*.

### *Yakovlevia intermedia*, new species

PLATE 471: FIGURES 1–17

Large for genus, transversely subrectangular in outline; hinge forming widest part; ears large, form-

ing angle of about 70°. Sides sloping medially; anterior margin broadly rounded and indented medially. Surface finely capillate, 3 to 5 capillae per 2 mm on trail of adult. Spines slender, arranged as described for genus.

Pedicle valve narrowly convex in lateral profile, angle of geniculation about 55°; posterior third nearly flat, venter narrowly rounded but anterior third slightly more convex than posterior third; anterior profile medially deeply indented dome with precipitous sides. Umbonal region nearly flat, with short and gentle slopes. Sulcus originating on anterior side of umbonal region, deep and fairly wide; flanks bounding sulcus swollen and with steep slopes; ears subcarinate in section, usually angular.

Brachial valve gently concave, deepest just posterior to place of geniculation; ears flatly concave, demarcated by broad, gentle fold toward pedicle valve. Fold low; sides and anterior margin steep.

Pedicle valve interior with narrow posterior pitted band but some specimens with well-developed smooth ginglymus. Muscle field strongly impressed with strongly developed and elevated lateral and anterior margins; adductor platform anteriorly strongly thickened and expanded. Interior surfaces outside muscle field strongly, or extravagantly granulose.

Brachial valve interior not well known but structures not greatly thickened; cardinal process small; lateral ridges poorly formed; brachial ridges not strongly defined.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706c							
151501a	25.3	23.2	44.0	45.2	36.0	18.0	8.2
(holotype)							
151501b	24.5	?	41.0	41.0	34.4	16.0	?
151501c	23.2	?	37.0	41.6	32.5	14.5	?
151501d	21.4	20.0	37.5	41.1	29.1	15.0	6.2
151501e	22.3	19.7	37.5?	37.6	30.0	12.7	6.1
151501f	20.6	?	32.5	36.8	28.1	12.3	?
151501g	19.9	17.8	24.0	38.0	28.3	6.9	1.5
151501h	18.0	?	26.0	35.3	25.5	8.5	?

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank Member).

LOCALITY.—USNM 706c.

DIAGNOSIS.—Strongly sulcate *Yakovlevia* having a flattened visceral disc region.

TYPES.—Holotype: USNM 151501a. Figured

paratypes: USNM 151501b, c, e, g, h. Measured paratypes: USNM 151501b–h. Unfigured paratypes: USNM 151501d, f.

COMPARISON.—This species is most like *Y. hessorum* and *Y. indentata*, both new species, and is compared under those headings. *Yakovlevia intermedia* is rare in the China Tank Member of the Word Formation.

*Yakovlevia multistriata* (Meek)

PLATE 469: FIGURES 12–14

*Productus multistriatus* Meek, 1860:309; 1876:350, pl. 1: figs. 8a, b; 1877:76, pl. 8: figs. 3–3e.—Girty, 1920, pl. 56: figs. 7, 7a.

Large, thick-shelled, rectangular in outline, hinge equal to or slightly greater than midwidth; sides nearly straight or sloping slightly medially; anterior margin broadly rounded, moderately indented. Surface costellate, 11 per 5 mm on trail. Spine arrangement as described for genus.

Pedicle valve narrowly convex in lateral profile, posterior third of low convexity but anterior two-thirds strongly convex and venter narrowly convex. Angle of geniculation 20–50°. Anterior profile high with middle marked by broadly U-shaped depression with precipitous sides. Umbonal region and visceral disc swollen; umbonal slopes moderately long and steep. Sulcus originating near middle of visceral disc, broad and moderately deep. Flanks bounding sulcus moderately swollen. Trail long, far exceeding visceral disc in length. Ears not prominent in adults, variable, forming angle of 70° to nearly right angle.

Brachial valve gently concave, marked medially by low subcarinate fold dividing deepest part. Ears flattened and marked off by low flexure. Sides and anterior steep.

Pedicle valve interior with deeply impressed, subflabellate diductor scars and strongly elevated, thickened adductor platform.

Brachial valve interior greatly thickened, angle of geniculation nearly right angle. Cardinal process large, posterior platform thick; muscle field large, outside adductor scars strongly dendritic, inner scars elongate; brachial ridges thick and elevated. Trail long, with elevated rim demarcating visceral disc.

MEASUREMENTS. (in mm).—Brachial valve unmeasurable.

	length	sur- face length	hinge width	mid- width	height	thick- ness
USNM 776a						
646	34.0	68.0	4.8	42.0	23.0?	?
(holotype)						
646a	34.0	67.0	38.2	35.2	21.0	?
646b	33.0	58.0?	41.4	35.4	?	14.1
15131a	31.7	77.0	41.4	34.4	25.0?	?
15131b	33.2	70.0	43.0	36.4	21.0	?

STRATIGRAPHIC OCCURRENCE.—Phosphoria Formation.

LOCALITIES.—Widespread in Wyoming, Nevada and Utah. Not seen in Texas.

DIAGNOSIS.—Large *Yakovlevia* with greatly thickened shell and long trail.

TYPES.—Holotype: USNM 646. Measured paratypes: USNM 646a, b. Measured hypotypes: USNM 15131a, b.

COMPARISONS.—The only species in the Glass Mountains to which *Y. multistriata* can be profitably compared is *Y. hessorum*, new species, under which heading a detailed comparison is made.

*Yakovlevia multistriata* is seldom found in good preservation; it is usually distorted or partially mineralized. Its ornament is seldom seen, and the length and strength of its spines are not known. In its typical form this is a large and ponderous species but the Phosphoria Formation contains many specimens that deviate importantly from the typical form. It is thus likely that other species of *Yakovlevia* will be found among specimens from the Phosphoria Formation and its stratigraphic equivalents.

*Yakovlevia sulcata*, new species

PLATE 472: FIGURES 1–39

Medium size for genus, width at hinge nearly twice length and forming widest part; outline transversely rectangular. Sides sloping medially; anterior margin deeply indented. Surface costellate, 11 per 5 mm on trail slope. Spine arrangement as described for genus; spines slender, attaining length of 15 mm. Other spines few and scattered.

Pedicle valve lateral profile angular, venter very narrow, visceral region nearly flat, and trail gently convex; angle of geniculation near 60°. An-



terior profile broadly domed, dome forming two lobes with deep indentation between, sides sloping steeply. Beak small, umbonal region nearly flat not extending posterior to posterior line. Umbonal slope short and gentle. Sulcus originating 5–7 mm anterior to beak, shallow on visceral disc but deep and wide on venter and trail; flanks bounding sulcus swollen and prominent. Ears subangular in cross section and forming angle of 60–70°.

Brachial valve moderately concave, visceral disc region somewhat flattened and marked medially by prominent angular fold, most elevated posterior to place of geniculation. Areas of deepest concavity corresponding to flanks of pedicle valve. Ears gently concave, demarcated by low oblique fold.

Sides and anterior steep. Capillae well developed. Pedicle valve interior with grossly exaggerated muscle field, flabellate diductors surrounded by elevated thickening and adductor platform thick, greatly elevated, medially grooved. Median adductor scars elongate and looped. Posterior pitted band prominent.

Brachial valve interior with moderately developed lateral ridges bounding wide nodose band. Cardinal process small; posterior platform fairly well developed. Supporting ridge of cardinal process wide and thick, sending fingers between muscles. Adductor field small, inner adductor pair small; outer pair dendritic but small. Brachial ridges well developed. Endospines long and thick.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 707e							
151491a	18.7	17.4	26.0	34.6	31.0	10.6	4.3
151491b	18.1	16.3	29.0	34.5	27.3	12.0	6.7
151491c	17.0	15.6	23.5	33.9	28.0	9.8	4.3
151491d	17.0	16.0	27.0	30.1	27.3	10.7	5.8
151491e	16.9	15.0	22.0	29.6	24.7	9.1	4.1
151491f	15.8	14.9	18.0	29.7	25.4	5.1	2.0
151491g	12.3	11.4	13.5	21.6	19.0	3.1	0.9
(holotype)							
151491h	10.5	9.7	11.0	22.8	18.4	2.4	0.4

STRATIGRAPHIC OCCURRENCE.—Road Canyon and Ross Mine formations.

LOCALITIES.—AMNH 509; USNM 707e, 716xa, 721j, 721y, 722e, 722g, 723x, 724a, 726d, 732j, 736x. Ross Mine: USNM 733z.

DIAGNOSIS.—Transverse *Yakovlevia* finely costellate and with the hinge about twice the valve length.

TYPES.—Holotype: USNM 151491g. Figured paratypes: USNM 151490a, b; 151491e, h–o 154041a, b, d, e; 154042. Measured paratypes: USNM 151491a–f, h. Unfigured paratypes: USNM 151491a–d, f; 154041c.

COMPARISON.—*Yakovlevia sulcata* may be compared closely with *Y. transversa* (Cooper) from the Permian of Oregon. The two species share a transverse outline, wide hinge, and some other features, but the former nevertheless differs importantly from the latter, which tends to a somewhat larger size and somewhat less proportional width. The

ornament of *Y. sulcata* is finer than that of *Y. transversa* which has 8 costellae in 5 mm, compared with 11 for the Glass Mountains species. The most striking difference between the two species is the much deeper sulcus in *Y. sulcata* and the somewhat sharper geniculation. The interior of *Y. transversa* is not known, but the largest specimen in the collection has a depth of only 5 mm. Consequently it is believed that the interior would be much less thickened than that of the Glass Mountains species, a condition unusual in this respect.

*Yakovlevia?* species

*Productus guadalupensis* Girty, 1909:261, pl. 22: figs. 3, 3a.

This specimen is a dolomite filling of the interior of a pedicle valve showing the characteristic subflabelliform muscle scar of *Yakovlevia*. Also visible and characteristic are a short ginglymus suggesting an interarea and a scar of a large spine

near the place of geniculation on one side of the specimen. The whole inner surface is endospinose. The species is unlike *Y. costellata*, new species, the only described *Yakovlevia* from the Guadalupe Mountain region. It differs in being smaller, having a less extended shell, and in having a smaller muscle region. This is probably an undescribed species of *Yakovlevia* or *Paucispinifera*, but more material of it is needed.

Girty's figured specimen: USNM 118529.

STRATIGRAPHIC OCCURRENCE.—Delaware Mountain Formation (= Cherry Canyon Formation—"sub-Getaway Fossil Zone" of P. B. King (1948:41) = the 100 or 200 feet of beds that separate the top of the Brushy Canyon Formation from the base of the Getaway Limestone Member of the Cherry Canyon Formation).

LOCALITY.—USGS 2931.

### *Siphonosia*, new genus

[Greek *siphonos* (pipe)]

Medium size, elongate oval outline, anterior part of pedicle valve produced into short trumpet-like tube; hinge generally less than maximum width but often not well defined. Beak small, usually with small flattened cicatrix, often eroded away; surface with low, narrow, concentric wrinkles crossed by fine costellae increasing generally by implantation. Rhizoid spines confined to posterior margin and flanks. Body spines short, scattered over surface. No spines on brachial valve.

Pedicle valve cuplike, sides strongly extended in dorsad direction to deepen cup; muscle area triangular, diductor scars widely triangular located on each side of shell anterior to beak. Adductor scars not clearly discernible probably located near apex, where short myophragm appears in one specimen. Peripheral rim broad, rarely strongly pronounced.

Brachial valve gently concave to nearly flat; costellate but without spines. Lophidium narrowly rounded, partially engulfing distal part of cardinal process. Cardinal margin corrugated. Cardinal process bilobed, lobes narrow, pressed closely together, sessile. Median ridge thick and low distally near cardinal process, but dividing slightly anteriorly, proximal divided part surrounding distal end of thin median ridge. Brachial ridges long and

slender, closely pressed against elevated and rounded lateral rim. Lateral rims extended around anterior margin.

TYPE-SPECIES.—*Siphonosia alleni*, new species.

DIAGNOSIS.—Like *Proboscidea* but with short "proboscis," poorly defined hinge and cardinal region; low thick median ridge in the brachial valve and a lophidium over the cardinal process.

COMPARISON.—Direct comparison need only be made with *Proboscidea* Oehlert. Other proboscideiform genera such as *Tubaria* Muir-Wood and Cooper are obviously differently derived than *Siphonosia* and *Proboscidea*. The convergence of the latter two genera is almost precise but the few minor differences discernible suggest that the Mississippian and Permian genera are derived from different linoproductid ancestors.

In Mississippian *Proboscidea* the tubular projection on the anterior of the pedicle valve is much longer than that of *Siphonosia*. We have only one completely siphonate specimen of the Permian genus but it is the oldest specimen in terms of growth that we have. It is clearly an adult and is certainly full grown. The Visean species commonly has a strongly elevated rim around the pedicle valve but the corresponding rim in the Permian species is low and broad, much less conspicuous than that of *Proboscidea*. The hinge region of *Proboscidea* is much more regular than that of the Permian genus and usually has well-defined ears. Ears are not developed on the pedicle valve of *Siphonosia* but they may appear on the brachial valve where one ear may be developed but not the other.

The median ridge of the brachial valve of *Proboscidea* is usually thin and low in contrast to the broad thick one of *Siphonosia*. In the latter genus the median ridge is divided and the ends surround a low thin ridge which in turn is anteriorly divided. The broad divided ridge suggests the Upper Permian *Stepanoviella* of Zavodowsky.

The so-called brachial ridges are low and indistinct but they are characterized by great length and the impingement against the elevated lateral margin. The cardinal process lobes are low and have narrow myophores. They are sessile on the platform produced by the median ridge but the individual lobes are thickened in an anterior direction like those of some of the Aulostegidae. The lophidium appears to be a late development in the

calcification of the shell and parts of it fill the space between the cardinal process lobes.

DISCUSSION.—The beak characters of *Siphonositia* suggest those of *Compressoproductus* Sarycheva but the cardinal process is clearly linoproductid and suggests that origin of the genus is in some stock of this group in Early Permian time. The genus is very rare in the Glass Mountains and has only been found in the lower Cathedral Mountain at USNM 721u. The 34 specimens in the collection are the result of the solution of about 25 blocks, more than a ton of rock.

*Siphonositia allenii*, new species

PLATE 466: FIGURES 1–32; PLATE 467: FIGURES 1–8; PLATE 468: FIGURES 23–28

Medium size, longer than wide; hinge narrower than maximum shell width near midvalve or slightly anterior; anterior margin narrowly rounded. Beak small, umbo only slightly extended posterior to hinge; ears small when defined, slightly deflected in ventral direction. Cicatrix of attachment small, surface costellate, costellae separated by spaces as wide or wider than costellae; 2 costellae per mm at anterior; posterior and sides concentrically and finely wrinkled. Rhizoid spines fine, confined to posterolateral areas. Body spines short, oblique, scattered.

Pedicle valve anterior drawn into short tube; lateral profile gently convex posterior to tube and bent at right angles to profile anterior to tube. Anterior profile narrow, steep dome with nearly vertical sides. Umbonal region narrowly swollen for short distance but merging into moderately median region posterior to tube; lateral slopes vertical to ventral surface of valve; anterior slope also bent vertical to valve surface. Tube short, subcircular distally but transversely elliptical at proximal end.

Brachial valve gently concave to nearly flat, expanding slightly anteriorly to widest part; ears small. Umbonal region small but deep depression, marked by small smooth elevation representing initial shell stage.

Pedicle valve interior with visceral region outlined by broad rim separating body chamber from valve walls; muscular field apical, diductors forming flabellate scar separated anteriorly by short me-

dian ridge probably marking site of adductor scars.

Brachial valve interior with corrugated hinge margin; cardinal process small, bilobed, lobes thickened toward anterior. Peripheral rim narrow; brachial ridges elongate and lateral. Median ridge thick, divided on each side of low thin ridge just posterior to midvalve.

MEASUREMENTS (in mm).—Brachial valve length, and thickness, unmeasurable.

	length	sur- face length	hinge width	mid- width	height	tube
USNM 721u						
152789a	17.4	28.0	7.7	15.8	10.3	6.0
(holotype)						
152789b	16.9	28.0	8.3	16.1	11.0	1.5
152789c	16.3	27.0	8.6	14.1	9.6	2.5?
152789d	16.4	21.0	5.0	14.0	7.4	1.3
152789e	16.9	18.0	7.8	15.3	7.1	none
152789f	13.7	14.0	7.8	13.0	4.7	none

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITY.—USNM 721u.

DIAGNOSIS.—*Siphonositia* with a short anterior tube.

TYPES.—Holotype: USNM 152789a. Figured paratypes: USNM 152789d, e, o–u; 153919. Measured paratypes: USNM 152789b–f. Unfigured paratypes: USNM 152789b, c, f–n.

COMPARISON.—Differs from *Proboscidea proboscidea* (Verneuil) in the larger size and much shorter tube. Nothing else like it is known from the Permian.

DISCUSSION.—This description is based on 24 pedicle and 2 brachial valves which show almost the complete development of the shell. The development of the pedicle valve seems to be the same as that of the Mississippian *Proboscidea* as indicated by Muir-Wood and Cooper (1960:325). The smallest specimen is about 9 mm long and 9 mm wide. It is very shallow and has a rim around the inside margin. The rim widens as growth continues, becoming 2 mm wide when the length of 16 mm is attained. It is at about this length that the tube begins to form. At, or nearly at, this length the shell margin outside the rim bends abruptly in a dorsal direction and starts to grow at about right angles to the marginal rim. Anteriorly the front margin is deflected slightly ventrad. The antero-

lateral margins grow mediodorsally as narrow bands to unite at midvalve and form the dorsal side of the tube. After junction, growth is continued anteriorly to form a crudely circular tube. At the junction of the anteromedian shell flaps, the valve opens through a wide transverse hole which is later converted into the circular tube.

This rare species is named for Mr. David Allen of Kyle, Texas, who helped us in many ways in our field work when he was manager of the Iron Mountain Ranch in the Glass Mountains.

#### Subfamily ANIDANTHINAE Waterhouse, 1968

Transverse Linoproductidae with large or extended ears, fine costellae on pedicle valve, cancellate brachial valve with numerous broken trails; spines few, confined to pedicle valve, apparently all halteroid; cardinal process linoproductid.

Genus in West Texas: *Megousia* Muir-Wood and Cooper (1960).

*Megousia* is the most common linoproductid in the Glass Mountains, occurring in great numbers in the upper Cathedral Mountain Formation and in the Road Canyon Formation; it is rare in the Guadalupe Mountains. The other two genera of the subfamily, *Anidanthus* Whitehouse and *Kuvelousia* Waterhouse, are Austral and Boreal forms locally abundant in their respective provinces.

#### Genus *Megousia* Muir-Wood and Cooper, 1960

*Megousia* Muir-Wood and Cooper, 1960:309.—Williams et al., 1965:H501; Waterhouse, 1968:1171.

Small, transversely elliptical to subrectangular in outline; hinge forming greatest width; brachial valve usually elaborately alate; concavo-convex, with fairly deep visceral cavity. Anterior commissure usually broadly curved but tending to be subnasute. Surface costellate; pedicle valve spinose. Costellae of pedicle valve uninterrupted, those of brachial valve broken by thin lamellae representing abandoned trails. Spines usually scattered, consisting of row along posterior margin and sparse, erect to suberect spines on visceral disc region and trail. Ear spines commonly very long. Young with elaborate umbonal attachments.

Pedicle valve interior with large and flabellate diductor scars anteriorly separated by low platform; adductor scars inserted at posterior of platform. Ears large, alate but without baffles.

Brachial valve interior with small short-shafted cardinal process bilobed in young but becoming tri- to quadrilobed in adults; brevisseptum short, continuous with posterior platform; brachial ridges oblique, low, continuous with ear baffles; adductor scars small, consisting of posterior pair lying outside inner pair (divisible into four scars); brachial ridges broadly looped; anterior margin with poorly defined inner ridge.

TYPE-SPECIES.—*Megousia auriculata* Muir-Wood and Cooper (1960:310, pl. 113: figs. 1–11).

DIAGNOSIS.—Usually small, transverse Linoproductidae with elaborate, lateral wings on the brachial valve.

COMPARISON.—The genus most like *Megousia* is *Anidanthus* Whitehouse. The major distinction between the two is in the development of the elaborate wings on the lateral extremities of the brachial valve of *Megousia*. This feature does not occur in *Anidanthus*, suggesting, therefore, a small *Lino-productus* except for the development of the piled-up trails on the brachial valve. The interiors of *Megousia* and *Anidanthus* are identical, consequently the wing or big ear of the brachial valve is the major distinction and may indicate a difference in living habits between the two genera.

Waterhouse (1968:1175) established the genus *Kuvelousia* for large Boreal forms related to *Megousia* and *Anidanthus*, but distinguished by its large size, great convexity of the pedicle valve, proportionately finer costellation, thick and wedge-shaped brachial valve, and perhaps also by proportionately smaller ears. This genus is not present in West Texas; its southernmost known occurrence is in the Permian of Oregon.

The fine ornament (costellae) of this genus is commonly so variable within species that its value as a specific character may be questioned. Increase in costellae is brought about by intercalation and this takes place generally in three generations. One of these appears at an early stage when the shell is very small, another takes place on the umbonal region. In all the Glass Mountains species few costellae are intercalated on the venter and in some species on the posterior part of the trail slope. In all

species, however, on the anterior portion of the trail slope a sudden intercalation of many costellae takes place. Most specimens consequently have the anterior half or more of the trail slope with more numerous and finer costellae than appear on the venter or, perhaps, the umbonal region.

Another common feature in many specimens of this genus is the crowding of fine costellae in the center part of the anterior trail slope and, in still other specimens of several species, of the irregular direction taken by these finer costellae. In some specimens these converge medially, and costellae are pinched out by this convergence. Some costellae are wavy and irregular.

DISCUSSION.—The spine arrangement of *Megousia* is seldom preserved completely on any specimens. Fortunately enough specimens are present in the collection to permit an understanding of the spines. These may be separated for discussion into hinge spines and body spines, both of which appear to be of the halteroid type. The posterior margin is adorned on each side of the umbo by a row of spines that increase in size outward, the final spine located on the tip of the cardinal extremity is of considerable length for such small shells. One specimen 7 mm wide has an ear spine 22 mm long. The spine adjacent to the end spine may also be of considerable length, in some specimens attaining approximately the same length as the end spine. These posterior spines in *M. auriculata* Muir-Wood and Cooper extend at a fairly low angle from the hinge margin, about 20° or less for the end spines but considerably higher for the inside spines.

The body spines are long and slender, arising at an angle of about 45° and extending away from the shell in a strong curve toward the anterior margin. The most forward of the spines hang over the anterior margin. These spines must have been largely buried in the mud and would have helped to hold the shell in place. No trace of spines occurs on the brachial valve.

Any discussion of the posterior marginal spines must also include remarks on the cardinal extremities of the pedicle valve. This feature is most exaggerated in *M. auriculata*, in which the extremities are long sharp points extending out 5 mm or more from the margins in a specimen 18 mm long. This point usually bears a large spine at its extremity, and many have another spine inside the

distal one. This narrow ear abuts against the flattened margin of the large curved ear or wing of the opposite valve. In some of the larger species this ear is not so acute; it is, nevertheless, usually acutely angular, and the ears form a small triangle.

The exterior of the brachial valve is even more complicated than that of the pedicle valve. The ornament consists of fine concentric undulations that cancellate the radial costellae and thereby produce a reticulate pattern, best developed in the posterior half. Anterior the valve becomes lamellose by the production of a series of trails that are successively abandoned as growth continues.

The ear, or wing, of the brachial valve is most remarkable for its length and direction. It is most elaborately developed in *M. auriculata*, in which it is bifurcated. The wing also has its own costellate ornament, which has a different direction from that of the main part of the shell. The wing is built out at successive stages of growth, each lamella sharing in its growth. It extends laterally where successive lamellae join its anterior edge, thus widening the wing. Distally it forms a sweeping curve toward the anterior and in a different plane from that of the brachial valve. Usually it is strongly bent ventrally. In *M. auriculata* the ear splits distally, part extending laterally along the line of the hinge and fitting closely against the narrow ear of the pedicle valve, the other curving anterolaterally and extending, in some specimens, anterior to the anterior margin of the valve. In curving anteriorly many of these wings turn in such a way that the inner edge is perpendicular to the valve surface.

The interior of the pedicle valve is not developed in the same way in all species. *Megousia auriculata* has the most exaggerated development because of its great transverse extent and the strong enrollment of the pedicle valve. A prominent ear baffle is developed to form a deep chamber between the ear of the pedicle valve and the wing of the brachial valve, and this is the only species that has developed such a structure. Except for differences in details of the musculature, the pedicle valves are similar internally.

Inside the brachial valve the cardinal process is somewhat variable among species; also, in any given species all degrees from strong bilobation through trilobation to quadrilobation are present in the same species. This is especially true in *M.*



*auriculata*, in which most forms are deeply bilobed, with lobes actually separated in the younger specimens. In trilobed forms the characteristic deep groove of the linoproductid appears. In some the groove is so deep that it cleaves the median lobe for a short distance, so that the cleft median lobe, combined with the strong lateral lobes, produce a quadrilobed cardinal process. The posterior, or myophore, face always appears trilobed except in the young, and the median lobe is usually broad and transversely striated. In rare cases it is small and almost engulfed by the elevated lateral lobes.

Lateral ridges are variously developed within the same species and among species. Generally they are not well formed. The cardinal process, usually located on a posterior platform, is best developed in the older specimens and especially in those with deep concavity. In many specimens the development of the platform and associated structures is typically linoproductid. The thick platform is excavated laterally in many specimens for reception of the edges of the pedicle valve. Usually a thick ridge extends anteriorly from the cardinal process to join the brevisseptum, forming a ridge seemingly continuous from the cardinal process to midvalve. In some specimens oblique ridges appear in the muscle field between the adductors, a condition which may suggest accessory septa.

The posterior margin is modified in some specimens to aid in articulation. In *M. definita*, new species, the lateral ridges are fairly thick and are slightly oblique to the posterior margin. Along the posterior margin the shell is coarsely granulose, a condition similar to that described for *Yakovlevia*.

The adductor scars are small, the median pair located beside the brevisseptum and somewhat anterior to the lateral or outside pair. Each member of the median pair is divisible into two scars, but their actual shape is difficult to determine. The brachial ridges originate between the adductor pairs as usual, but their descent is steeply anterolateral before they form their narrow loop anterior to midvalve. Most specimens are too delicate for the brachial ridges to have formed.

**GROWTH.**—All the species in which early stages have been found developed in essentially the same way, but with minor differences. The best developmental series was obtained for *M. auriculata*, the growth development of which is given in detail under that species.

### *Megousia auriculata* Muir-Wood and Cooper

PLATE 450: FIGURES 1–48; PLATE 451: FIGURES 1–49; PLATE 452: FIGURES 19–28; PLATE 453: FIGURES 13–24?; PLATE 463: FIGURES 5–8; PLATE 467: FIGURES 9–13

*Megousia auriculata* Muir-Wood and Cooper, 1960:310, pl. 113: figs. 1–11.

*Linoproductus waagenianus* R. E. King (not Girty), 1931:77, pl. 17: figs. 11–15.

Small, transversely elliptical in outline, wide-hinged, elaborately alate. Sides sloping medially; anterior margin broadly rounded to nearly straight. Deeply concavo-convex with anterior strongly curved, becoming subcylindrical. Surface costellate, costellae on umbo and venter strong and distant with wide interspaces, numbering about 7 per 5 mm near midvalve of adult or at anterior of young.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	maximum width	height	thickness
USNM 707e							
124108b	9.3	6.4	19.0	16.4	20.8	6.2	4.4
(holotype)							
124108e	10.9	8.0	22.0	20.8	26.4	7.2	4.2
149940e	10.7	7.5	22.0	25.3	30.0	7.8	4.1
149940g	7.7	6.3	13.0	17.0	23.0	4.8	3.1
149940i	11.2	8.0	26.0	28.5	30.6?	8.7	5.2
149940l	11.4	8.3	25.0	27.7?	31.3?	8.2	4.1
149940s	7.5	5.6	13.0	16.4?	18.2?	4.6	2.6
149940t	12.2	8.9?	29.0	24.3	30.3	9.6	5.5
USNM 703b							
149923	13.5	8.6	27.0	26.6	33.4	8.7	4.1

Costellae on trail increasing by intercalation to 10 to 11 in 5 mm at front margin. Posterior margin with row of stout spines, those on ears long and strong; body with scattered curved halteroid spines. Brachial valve exterior with anteriorly crowded lamellae.

Pedicle valve lateral profile almost hemispherical; anterior profile forming broad, steep-sided dome. Beak elaborately deformed by attachment processes and spines; umbonal region narrowly swollen for short distance but merging into swollen midvalve region. Umbonal and lateral slopes steep; anterior slope steep; ears narrow, usually mucronate.

Brachial valve deeply concave, deepest in umbonal and medial regions, flattening marginally and with abruptly geniculated short trail. Lamellae short and delicate, cancellating costellae.

Pedicle valve interior with strong ear baffles in adults forming triangular chamber; adductor pit deep, divided posteriorly by small myophragm. Diductors large and flabellate.

Brachial valve interior with small cardinal process, strong marginal ridge extending across ears; other interior features delicate.

STRATIGRAPHIC OCCURRENCE.—Bone Spring, Cibolo, Cathedral Mountain, and Road Canyon formations.

LOCALITIES.—Bone Spring: AMNH 369, 658; USNM 747. Cibolo: USNM 738g, 738-l. Cathedral Mountain: AMNH 500L: USNM 702, 702a<sup>1</sup>, 702a, 702b, 702 low, 702un, 703a<sup>1</sup>, 703b, 708, 709, 711q, 712o, 723x, 721u, 724n, 724s, 725v, 726o, 726u, 726y, 735b. Road Canyon: AMNH 503, 507, 509; USNM 702c, 703, 703a, 703c, 703d, 707e, 709c, 710h, 710i, 710u, 710z, 712t, 716x, 719x, 720d, 721j, 721r, 721s, 721t, 721x, 721y, 721z, 722e, 722g, 724a, 724b, 724c, 724j, 726d, 726z, 735a, 737y.

DIAGNOSIS.—Transversely subcylindrical *Megousia* with long, slender, curved winglike ears.

TYPES.—Holotype: USNM 124108b. Figured paratypes: USNM 124108c. Measured paratypes: USNM 124108e, f. Figured hypotypes: USNM 149915; 149923; 149924; 149925a-e; 149929a-o, q, s-v, x; 149936; 149940n, r, u; 153971a, b; 153976a-d; 154026. Measured hypotypes: USNM 149940 e, g, i, l, s, t; 149923. Figured specimens: USNM 153929a, b; 153930.

COMPARISONS.—*Megousia auriculata* in its most abundant form is generally nearly two times as wide as long and has the most elaborate development of

the ears of any species in the Glass Mountains. Its great width and shortness are characteristic features. Another is the deep cleft in the posterior part of the ear where the hinge projects and is set off from the ear by an angular cleft. Other species have this character but usually are differently proportioned. *Megousia auriculata*, because of its form and the great development of the ears, is thus distinct from all other Glass Mountains species.

DISCUSSION.—As identified here, *M. auriculata* is a somewhat variable species. It varies in its outline and the proportion of length to width, but this is not unusual; the more troublesome variation is in the ornamentation, in which some coarsely costellate specimens occur with more finely ribbed ones. Furthermore, certain localities (e. g., USNM 702c) appear to have more coarsely costellate specimens dominating the finer ones. The genus is rare at that place but the majority of specimens appear to be more strongly costellate than specimens from USNM 707e where the species is so abundant and typical. A few strongly costellate forms appear at USNM 702 but they are outnumbered by the more typical specimens. The strongly costellate specimens from USNM 702c have the characteristic subcylindrical form of the species and appear to be typical in this respect.

*Megousia auriculata* has the ear more strongly developed than any other species. In some it is prolonged in an anterolateral direction beyond the anterior margin of the shell. A specimen 7 mm long has an ear about 11 mm in length. So strong is the curvature that some ears make a sweeping curve embracing an angle of almost 90°. In its curvature the ear is, in many specimens, rotated so that its outer edge is at right angles to the plane of the valve. This enormous ear would have assisted in keeping the individual on its convex side in the mud and may have assisted in feeding by creating an intake canal at the angle just anterior to the ear.

GROWTH.—An exceptionally fine series of immature specimens, mostly from USNM 707e, shows to perfection the early stages of growth. The smallest specimen, about 1.5 mm in diameter, has an umbonal ring and three body spines. No hinge spines have yet formed. The first spines appear on the angle of the ears at 3 mm width, with the length of this specimen 2.5 mm. The second pair of posterior marginal spines appears at 6 mm and the third pair at 10 mm width. The spines along the pos-

terior margin attain a length of 7.5 mm and may extend at any angle. It is common for them to project at right angles to the posterior margin. At these widths the maximum width is near midvalve, but ears begin to develop at about the 10-mm, or three-spine, stage. These become prominent after the shell reaches this midwidth, but no specimens show a series of developmental stages of the ear of the brachial valve.

Certain features of the immature specimens deserve further attention. The umbo of all specimens is deformed and bears a peculiar callus structure. This takes the form of a small ellipse elongated in the direction of shell length. This elliptical callosity bears a median slit. It is commonly elongated in a posterior direction and is distally free of the valve. At its free end it is divided and in some specimens gives out a large rhizoid spine at various angles to the midline from each side. The free end is used to help in attachment. This elliptical callosity is retained by the majority of specimens into late adulthood.

Posteroventral to the callosity is the cicatrix that reflects the surface on which the little *Megousia* attached, rough in some, a groove in others but a broad, smooth flat area in a few. The cicatrix is on the summit of the umbonal region. On its most ventral point a spine appears on each side of the cicatrix and normally forms a ring over it. The ring is commonly formed of two spines but more rarely it is composed of two or three pairs of spines. In other rare specimens the spines instead of converging to form a ring diverge widely, as much as 180° in some specimens, to spread out on a flat surface of attachment. The spine ring commonly clasps a crinoid stem or round bryozoan frond.

An interesting aberration of the ring suggests the

formation of a knot by the spine pair. Most commonly the spines merely cross, but some meet and join to produce a single elongated spine. The ring twines around another productid spine and then unites and continues to grow as a single spine beyond the ring.

### *Megousia definita*, new species

PLATE 449: FIGURES 1-46

Large for genus transversely rectangular to subquadrate in outline. Sides gently curved sloping medially; anterior margin broadly rounded to nearly flat. Hinge forming widest part. Ears prominent, bluntly pointed but forming acute angle (70°). Surface costellae of pedicle valve stronger than on brachial valve, strongest on umbonal and visceral regions, more crowded on trail; costellae broad and numbering 6 to 8 in 5 mm on umbonal region just posterior to trail, and 10 to 12 in 5 mm at anterior margin, increasing by intercalation. Pedicle valve sparsely spinose, row of 5 to 7 on posterior margin, with 2 of these large and long on ear; body spines few and scattered.

Pedicle valve unevenly convex in lateral profile, greatest curvature in umbonal region; anterior profile forming broad, high, steep-sided dome. Beak small and narrow but widening rapidly into swollen umbonal region; median region strongly inflated but flattened on long sloping trail; sulcus broad and shallow originating on venter, usually poorly defined and not clear on all specimens. Flanks rounded and steep. Umbonal slopes steep.

Brachial valve deeply concave, deepest in mid-region and with steeply sloping sides. Ears defined by low oblique ridge where rugae are strongest. Ears

#### MEASUREMENTS (in mm).—

	length	brachial valve length	maximum width	surface length	hinge width	midwidth	height	thickness
USNM 706e								
149953a	16.0	13.7	30.5	30.0?	26.7	21.8	11.4?	5.7
(holotype)								
149953b	20.4	15.4	29.0?	40.0	27.7	22.5	12.3	5.8
149953c	18.2	13.3	?	35.0?	25.0	20.0	11.0	6.1
149953d	18.4	13.5	27.0	39.0	25.8	21.7	11.9	4.6
149953e	15.5	13.2	28.6	27.0?	26.2	20.3	8.7	4.6
149953f	16.8	14.4	26.0	31.0?	25.4	21.2	9.2	5.0

gently concave proximally but forming broad, flat, somewhat twisted triangle distally. Ears not prolonged anteriorly but narrowly rounded in this direction. Trail lamellae crowded and delicate anteriorly.

Pedicle valve interior with adductors inserted in pit posterior to thickened platform; diductors wide and flabellate. Posterior part with lateral thickening extending from beak to ears; ear baffles weak.

Brachial valve interior with small cardinal process on thick posterior platform; median ridge buttressing cardinal process and extending anteriorly to engulf posterior part of brevisseptum; ear baffles strong and continued anteriorly as marginal ridge. Lateral ridges extending to ear baffles but not strong. Brachial ridges moderately well developed.

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank, Willis Ranch, Appel Ranch members and lens between the last two), Cherry Canyon Formation (Getaway Member).

LOCALITIES.—China Tank: USNM 706a, 706c. Willis Ranch: AMNH 505, 506; USNM 706, 706e, 718d, 723w. Appel Ranch: USNM 715i, 719z, 722t, 727j. Lens: USNM 706b. Getaway: AMNH 519, Moore 31, USNM 732.

DIAGNOSIS.—Large subrectangular to subquadrate *Megousia* having short narrowly curved ears and fairly even costellae.

TYPES.—Holotype: USNM 149953a. Figured paratypes: USNM 149952a–c; 149953b, d, g–i; 153975a. Measured paratypes: USNM 149953b–f. Unfigured paratypes: USNM 149953c, e, f.

COMPARISONS.—This species is comparable to other Word species such as *M. mucronata*, *M. flexuosa*, and the Leonardian *M. umbonata*, all new species. It differs from the first of these in having a more compact and more nearly quadrate form, in having broader and more even costellae, with the spines on the posterior margin given off at a higher angle and not hugging the posterior margin as they do in *M. mucronata*. The form of the ear in *M. definita* is also different from that of *M. mucronata*. In the latter it is moderately extended and tapers to a sharp point but in *M. definita* the ear is abruptly and narrowly curved in a ventral direction to fold over the lateral margin of the pedicle valve.

*Megousia flexuosa* attains about the same size as that of *M. definita* but large specimens are rare. At its maximum, *M. flexuosa* is still somewhat more

transverse than *M. definita* but in its more common smaller form it is distinctly more transverse and more extended along the hinge than the latter. The costellae of *M. flexuosa* are somewhat finer and usually less regularly developed than those of *M. definita*. The latter species is generally more umbonate than the one from the upper part of the Willis Ranch Member.

Although *Megousia umbonata* is a variable species like all others of this genus, it seldom attains the size of *M. definita* and it is usually more transverse than the latter. The most distinctive feature of *M. umbonata* is its inflated umbonal region, which protrudes far beyond the posterior margin, farther than in any other species from the Glass Mountains. The costellae of *M. umbonata* are usually finer and more variable than those of *M. definita*.

DISCUSSION.—Old specimens of this species afford information on interior details seldom seen in other specimens. The ears are strongly deflected in a dorsal direction and are separated from the remainder of the valve. Ear baffles are formed across the ears in both valves but are strong only in the brachial valve. The sloping side just anterior to the baffle is strongly striated and the shell toward the interior is pitted. The ear baffles unite with the marginal ridge, which is strong. The baffles also unite with the fairly strong lateral ridges. Brachial ridges are best developed in this of all the species studied.

The young, as indicated by three immature specimens, must have developed in a manner similar to that described for *M. auriculata* Muir-Wood and Cooper. The beak is occupied by a small callosity bearing a median slit similar to that of *M. auriculata* but not nearly so large. The attachment ring appears to have been nearer the beak and in the smallest specimens consists of two rings close together. Several fairly long body spines appear on these small specimens, of which the smallest is 4 mm long.

OCCURRENCE.—As indicated by the specimens in the collection, this species had a fairly long range. The oldest specimens were taken from USNM 706, which represents the lower part of the Willis Ranch Member. The species is rare in the upper part of this member, but because of the large quantity of blocks processed from this locality a fair number of specimens is available. *Megousia definita* appears to be somewhat more abundant in the Appel Ranch

Member, but the specimens are commonly distorted, at least at the places collected during this study.

*Megousia flexuosa*, new species

PLATE 447: FIGURES 1-39

Large for genus, transversely rectangular to subelliptical in outline, hinge forming widest part. Sides nearly straight to gently curved and sloping strongly medially; anterior margin broadly and gently rounded. Costellae variable, 8 to 12 per 5 mm on venter and 11 to 18 per 5 mm at front margin. Rugae developed just inside ears. Halteroid spines prominent in row 6 to 8 slender spines arising at high angle ( $50^\circ$ ) to posterior margin. Body spines variable in development, scattered, slender, not usually numerous.

Pedicle valve strongly and unevenly convex in lateral profile, maximum curvature on venter and umbonal region, trail forming long, gently curved slope. Anterior profile broad, steep-sided dome.

Beak small; umbonal region inflated, protruding broadly for substantial distance posterior to posterior margin. Median region swollen, sides and anterior slope steep. Sulcus obscure, variable, not developed in all specimens, confined to venter and part of trail. Ear pointed, slender.

Brachial valve deeply concave, sides steep; most concave medially. Ear not strongly demarcated by ridge, faintly bilobed on outer margin, with strong lobe directed anterolaterally and twisted toward outside.

Pedicle valve interior with poorly developed adductor platform but widely divergent, flabellate diductor scars. Ear baffles not developed but area just anterior to ear strongly nodose.

Brachial valve interior with moderately large cardinal process and fairly strong lateral ridges extending to ears and forming low pitted baffle; posterior platform strong, extended anteriorly as buttress to cardinal process and joining brevisseptum. Brachial ridges not developed; marginal ridge strong.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706							
149946a	17.8	?	34.5	29.2	24.8	11.0	?
149946b	14.6	9.7	30.0?	25.4	19.7	10.2	5.6
(holotype)							
149946c	13.2	8.7	26.0	25.2?	19.9	8.7?	4.7
149946d	13.4	?	27.0	26.1	21.7	8.9	?
149946e	12.0	?	24.0	27.8	18.0	8.2	?
149946f	13.4	?	29.0	24.7	17.9	9.2	?
149946g	11.4	?	22.0	20.6	17.5	7.6	?
149946h	13.6	?	26.0	26.0	20.7	8.2	?
149946i	9.2	7.0	16.0	17.9	14.5	5.2	2.0

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank and Willis Ranch members).

LOCALITIES.—China Tank: USNM 706c. Willis Ranch: 706, 706e.

DIAGNOSIS.—Moderately large *Megousia* with fine costellae, spines on posterior margin arising at a high angle.

TYPES.—Holotype: USNM 149946b. Figured paratypes: USNM 149945a, b; 149946a, c, i-l. Measured paratypes: USNM 149946a, c-i. Unfigured paratypes: USNM 149946d-h.

COMPARISONS.—*Megousia flexuosa* differs from

*M. definita*, new species, in having a more transverse outline, more irregular costellae, and in the form of the ears. The ears of *M. definita* are short and narrowly curved toward the pedicle valve but those of *M. flexuosa* are longer, more slender, and extend laterally for a considerable distance.

*Megousia mucronata*, new species, differs in many ways from *M. flexuosa*. It is larger and strongly transverse, a feature emphasized by the directly lateral extension of the spines of the posterior margin. These tend to emphasize the great width of the cardinal extremities. *Megousia flexuosa* is less



strongly costellate than *M. mucronata* and the brachial valve is less lamellose.

DISCUSSION.—Four immature specimens ranging in length from 3 to 6 mm indicate developmental stages like those of *M. auriculata*. The beak has a small callosity and attachment ring or rings. The umbonal regions of these small shells are considerably deformed.

### *Megousia? girtyi* (R. E. King)

PLATE 452: FIGURES 1–5

*Linoproductus girtyi* R. E. King, 1931:76, pl. 17: figs. 3, 5 [not fig. 4].

This species is based on three specimens, one from the Word Formation and two from the Leonard (of P. B. King, 1931). All are small and without the natural boundaries of the specimens, a fact making their interpretation difficult. Except for one of the paratypes the locations are not clear. Specimen YPM 11501 is clearly located in a sequence, coming from the section through Sullivan Peak, said to be “some distance above the middle of bed 24, but below top of hill 4920” in section 12. The horizon is given by P. B. King as the “Third and Fourth Limestone Members” of the Leonard Formation. The label on the holotype, YPM 11507, is given as “Leonard, Western Glass Mountains (King locality Ax).” The third specimen (T 10681) comes from the Word Formation and is undoubtedly not the same species as the other two.

The ornamentation and beak characters are all that are available for study in the holotype and these are insufficient to identify this species with any other in the Glass Mountains. That the holotype is a *Megousia* seems clear from the character of its beak, which has the characteristic elongated callosity bearing a median slit. This is the only feature that definitely gives this specimen generic identity. The ornamentation is like that of the posterior part of several of the species described herein. The specimen is also moderately convex, with a fairly strongly incurved umbonal region. All the features visible suggest a young adult, possibly of *M. auriculata* Muir-Wood and Cooper or *M. umbonata*, a new species.

Paratype YPM 11501, which is well located in the sequence, has even less recognizable characters than the holotype. This specimen is less convex and some-

what more strongly costellate than the holotype, and these features indicate immaturity. It cannot be absolutely certain that this specimen is a *Megousia*, but the ornament is very similar to the young, coarse stage of *M. auriculata* or *M. umbonata*.

With present knowledge of this genus it seems impossible to recognize this species and link it to any of the better characterized species. The holotype is so poorly preserved that good specific characters, which must include those of the brachial valve, cannot be determined. It therefore seems best to assign the species to *Megousia* but leave the specific name with the two type specimens.

### *Megousia mucronata*, new species

PLATE 446: FIGURES 34–41; PLATE 448: FIGURES 1–11?, 12–42;  
PLATE 453: FIGURES 1–6

Large for genus, transversely rectangular in outline, hinge forming widest part and transversely produced. Sides sloping medially and gently curved; anterior margin broadly rounded to nearly straight. Surface variably costellate, costellae strongest on umbonal region and there numbering 6 to 9 per 5 mm; venter and trail variably costellate, depending on intercalations, but usually numbering 7 to 11 per 5 mm at or near anterior margin. Concentric wrinkles on both valves. Spines in row along hinge, each spine extending at low angle to hinge and lying in contact or almost in contact with next outer one, about 7 on posterior margin of adult. Body spines scattered and few, probably short.

Pedicle valve unevenly convex in lateral profile, umbonal region and venter forming most convex part, trail somewhat flattened; anterior profile strongly domed and steep-sided; beak small but umbonal region swollen and protruding considerably posterior to posterior margin and narrowly rounded in dorsal view. Umbonal slopes steep; median region strongly swollen; sulcus discernible only on few specimens, usually poorly developed when present. Ears prominent, narrowly mucronate, extension being emphasized by two large subparallel halteroid spines.

Brachial valve deeply but unevenly concave, deepest part at umbonal region and just to anterior; ears defined by low ridge, flattened and extended distally with short, slender triangular expansion.

Concentric lamellae thin and delicate. Sides sloping steeply.

Pedicle valve interior with slight development of adductor platform but large flabellate diductor scars. No ear baffles, but strong nodes appearing just anterior to ears on ridges produced by outer undulations concentrated at ears.

Brachial valve interior with moderately large cardinal process on well-developed posterior platform; lateral ridges moderately developed; median ridge buttressing cardinal process moderately thick; ear baffles slightly developed, corrugated; brachial ridges poorly developed, seen only in old adults; anterior marginal ridge strong.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	maximum width	height	thickness
USNM 706c								
149944a	17.0	13.2	34.0	35.8	26.3	36.2?	10.8	5.5
(holotype)								
149944b	20.5	?	39.0	38.4	31.2	45.0?	12.2	?
149944c	16.9	?	32.0	32.5	26.7	34.6?	9.8	?
149944d	17.2	?	37.5	32.8	25.6	32.8	11.8	?
149944e	17.2	?	30.0	29.3	22.3	29.3	9.8	?
149944f	17.7	12.8	31.0	26.4?	23.4	?	9.8	4.7
149944g	14.6	10.8	28.0	26.4	23.5	29.4	9.2	4.9
149944h	12.0	10.0	23.0	27.1	19.3	27.1	7.8	4.8
149944q	15.0	?	27.0	27.3	22.4	27.3	8.7	?
149944r	11.2	9.6	19.0	23.4	16.8?	23.4	6.4	2.7
149944s	8.9	7.8	12.0	13.6	10.6	13.6	3.4	1.9
USNM 732j								
153913a	18.3	12.0	33.0	39.6	24.6	39.6	10.7	7.0
153913c	17.3	11.5	33.0	24.0+	22.2	?	10.0	7.0

DIAGNOSIS.—Large, generally strongly costellate *Megousia* having strongly mucronate ears on the pedicle valve and the halteroid spines nearly parallel to the posterior margin.

Types.—Holotype: USNM 149944a. Figured paratypes: USNM 149943a, b; 149944b, c, k–m; 153913a, b. Measured paratypes: USNM 149944b–h, q–s; 153913a, c. Unfigured paratypes: USNM 149944d–j. Figured specimens: USNM 153974a, b.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation, Word Formation (China Tank and Willis Ranch members).

LOCALITIES.—Road Canyon: USNM 700v, 721j, 732i, 732j, 736x. Word: USNM 732s. China Tank: USNM 706c, 713, 726r, 726s, 733q. Willis Ranch: USNM 706.

COMPARISONS.—As the largest *Megousia* species occurring in the Glass Mountains this need not be compared in detail to the smaller species such as *M. auriculata* and *M. flexuosa*, both new. This species is readily distinguished from *M. definita*, new species, by its more transverse outline, strongly

mucronate ears, halteroid spines lying close on the posterior margin, and the much stronger costellae. Its stronger ornamentation, mucronate ears, and less umbonate pedicle valve distinguish *M. mucronata* from *M. umbonata*, new species.

DISCUSSION.—In external form this species has fair uniformity. It is naturally variable but the variability is not as great as that exhibited by the costellae. Some specimens are so strongly costellate as to be mistaken for a different species. The end members of the species seem utterly unlike, except for shape, yet all degrees of costellae size and arrangement intervene. The variation appears due to two causes: an initial variation in the number of costellae in the early stages of growth, and difference in insertion of new costellae. The first of these suggests specific difference, but not enough immature specimens are present for the observer to make sure of initial patterns or to determine if these are constant. Early intercalation may be followed by sparse intercalations or a resting stage, especially on the venter. Nearly all specimens show a

stage of numerous intercalations on the trail slope at varying distances from the margin. The trail in all adult specimens usually has the greatest number of costellae. A certain crowding can also be detected in the umbonal region. The postumbonal slope and venter usually are the sites of very little intercalation and are, therefore, the portion of the valve having the strongest costellae.

Variation of costellae involves their size and configuration as well as number. In some young specimens the costellae of the umbonal region or early stages of the valve are narrow, elevated, and separated by grooves wider than the width of the costellae. This form may continue throughout growth and yield an adult with fine distant constellae on the venter but, on the trail, where intercalation is sudden and numerous, the costellae are crowded and threadlike. In other specimens the venter is ornamented by strong costellae separated by spaces of about equal width and the final intercalation takes place near the anterior margin or not at all. These specimens are in marked contrast to those mentioned above. There are intermediates in which the costellae of the umbonal region are fairly strong and numerous but intercalation is indifferent or not at all on the venter, but high on the trail slope a crowd of new costellae appears. Such specimens, viewed from the front, are not unlike those that had numerous costellae initially. Larger collections may prove this species as now conceived to consist of more than one species, or perhaps subspecies.

**GROWTH.**—The growth of this species presents a slight difference from that observed in *M. auriculata*. The growth of the beak and umbo are essentially the same, except that in *M. mucronata* the callosity on the beak is smaller and the ring is nearer the beak. The difference lies in the fact that more of the posterior marginal spines share in the ring and that many of these spines, when not forming a ring, spread out to attach the shell in a manner similar to that seen in the Aulostegidae. That this genus remained attached until a fair size was attained is attested by the size of the ring and the number of spines forming it, as many as five, and in some actually attached specimens. One specimen with a well-formed ring is 11 mm long, and the largest specimen actually attached in its growth position is slightly over 9 mm long.

Specimens from the Road Canyon Formation

placed in this species have some minor differences. The brachial valves do not have strong concentric lamellae such as those shown by the China Tank specimens. This may be due to the harsh conditions suffered by these shells before burial. The Road Canyon specimens also are a little deeper than those from the Word. The umbonal region of Word specimens is variable, but many have the umbo only slightly protruding beyond the hinge, as is characteristic in the Road Canyon. Both groups are variable in ornamentation, the Word group somewhat more so, as it includes specimens with fairly coarse costellae.

### *Megousia umbonata*, new species

PLATE 447: FIGURES 40–48; PLATE 452: FIGURES 6–18

*Linoproductus waagenianus* R. E. King (not Girty), 1931:77, pl. 17: figs. 10a–c [only].

Medium size for genus, transversely but broadly subelliptical in outline; hinge forming greatest width; sides and anterior margin forming semicircle; ears prominent, extended. Surface finely costellate, costellae on umbonal region numbering 9 to 11 per 5 mm, as do those on venter, but on anterior margin numbering 11 to 13 per 5 mm. Spines along posterior margin slender and arising at low angle, closely appressed to posterior margin, at least in adults. Body spines few and scattered.

Pedicle valve moderately and fairly evenly convex except in umbonal region, there strongly humped; anterior profile a broad, steep-sided dome. Beak small, deformed; umbonal region strongly inflated, protruding considerably posterior to posterior margin; umbonal slopes steep and rounded; median region inflated; trail slope and sides steep; ears bluntly pointed, marked by wrinkles, and forming angle of almost 90°.

Brachial valve deeply concave and strongly lamellose, greatest concavity just posterior to midvalve; sides and anterior sloping moderately steeply; ears well demarcated by low ridge, flattened and widely expanded, notched at posterolateral extremity, elongated posterolaterally.

Pedicle valve interior with broad but not strongly thickened adductor platform, diductor scars flabellate, surface granulose on anterior side of ears. Ear baffles strong, forming small chambers.

Brachial valve interior with low, moderately

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness	maximum width
USNM 707q								
149959a	16.8	11.7	34.0	22.6	20.8	11.0	6.4	24.2
(holotype)								
149959b	18.4	10.2	34.0	22.8	20.5	10.8	6.7	24.3
149959e	15.0	?	29.0?	18.9	16.1	11.0?	?	19.7
149959f	13.6	?	27.0?	15.2	15.3	9.7	?	16.3?
149959g	15.5	?	29.0	18.8	17.8	9.2	?	19.4

large cardinal process, with strong median buttress ridge, and fairly thick lateral ridges. Marginal ridge thick; area on anterior side of ears pitted; brachial ridges not developed.

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation (with abundant *Perrinites*).

LOCALITIES.—USNM 702, 702 low, 707q, 717g, 721v, 723k, 726u, 726v, 726w, 726y, 733m.

DIAGNOSIS.—Finely costellate *Megousia* with highly umbonate pedicle valve.

TYPES.—Holotype: USNM 149959a. Figured paratypes: USNM 149957; 149959b, c; 153977; 153978. Measured paratypes: USNM 149959b, e–g. Unfigured paratypes: USNM 149959d–g.

COMPARISONS.—In size and form this species suggests *M. definita*, and *M. flexuosa*, both new species, and *M. auriculata* Muir-Wood and Cooper. It differs from the former in being more transverse, in having a higher umbonal region, and in the form of the ear which is not abruptly curved as in *M. definita*.

*Megousia auriculata* is much wider and considerably shorter than *M. umbonata* and does not have the high umbonal region so characteristic of the latter; furthermore, the elaborate development of the ear is unique to *M. auriculata*. The chief difference between *M. flexuosa* and *M. umbonata* is in the lesser development of the umbonal region in the former and the more transverse outline of the former.

DISCUSSION.—As with *M. mucronata*, the costellae of *M. umbonata* are variable from specimen to specimen. In some the umbonal region is fairly coarse, but in others it is occupied by very fine costellae. Another frequent occurrence in this species is the presence, especially on the middle part of the trail toward the margin, of sinuous or

converging costellae and costellae that are pinched out anteriorly by neighboring costellae.

*Megousia? waageniana* (Girty)

*Productus waagenianus* Girty, 1909:253, pl. 12: figs. 6–7a.

This species is based on two specimens, a pedicle valve and the exterior impression of a brachial valve. The ears are damaged on both valves and the ornament is obscure. Two features are most characteristic of the pedicle valve. One is the fine, costellate ornament and the other is the development of a strongly nasute anterior. The brachial valve has distant strong concentric lamellae as usual in *Megousia* and *Anidanthus*. We were unfortunate in not obtaining any supplementary material of this species that would definitely establish its generic affinities and determine its complete characters. Specimens of probable *Megousia* from USNM 750b are few, poorly preserved, and totally unlike Girty's species. These are coarsely costellate and do not have the alate wing developed, probably because they are young.

STRATIGRAPHIC OCCURRENCE.—Capitan Formation.

LOCALITY.—USGS 2926 (green).

DIAGNOSIS.—*Megousia?* of medium size with finely costellate exterior and nasute anterior.

TYPES.—Lectotype: USNM 118520a. paratype: USNM 118520b.

## Subfamily STRIATIFERINAE Muir-Wood and Cooper, 1960

Aberrant Linoproductidae with extremely thin body cavity; cardinal process degenerate, with a single myophore lobe due to reduction of lateral

lobes; prominent bladelike median septum continuous with the cardinal process.

Genera in West Texas: *Striatifera* Chao, 1927. *Compressoproductus* Sarycheva, 1960.

*Striatifera* is a rare genus in the Wolfcampian Neal Ranch Formation and is not entirely typical of the genus. The Neal Ranch specimens are not referable to *Compressoproductus*, however, because they have a well-formed but narrow hinge which is lacking from *Compressoproductus*. The latter genus is uncommon except for a few localities and it occurs in all of the formations above the Gap-tank in the Glass Mountains. It is only known from the Capitan Formation in the Guadalupe Mountains.

Genus *Striatifera* Chao, 1927

*Striatifera* Chao, 1927:24.—Muir-Wood and Cooper, 1960:328.  
—Williams et al., 1965:H506.

We have placed one Glass Mountains species of striatiferiform brachiopods in *Striatifera* because of the development of a well-marked but narrow hinge line. *S. linoproductiformis*, new species, is different from all other species of this type of brachiopod which are here referred to *Compressoproductus* in having the hinge well developed.

*Striatifera linoproductiformis*, new species

PLATE 455: FIGURES 1, 2; PLATE 462: FIGURES 1–8; PLATE 463: FIGURES 14–25; PLATE 465: FIGURES 1–32; PLATE 475: FIGURES 11–13

Outline variable from widely to somewhat narrowly oval, with straight but narrow hinge; posterolateral margins straight, lateral margins strongly rounded; anterior margin usually narrowly rounded. Surface strongly undulated and capillate. Undulations irregular, strongest at posterior and on posterolateral regions and sides, becoming more distant or disappearing anteriorly or marginally. Capillae crowded and numbering from 17 to 20 per 5 mm at anterior of large specimens. Spines stout, long, rhizoid, mostly confined to margins from beak to anterior margin. Occasional spines on umbo; body spines sporadic.

Pedicle valve with variable profile, usually moderately convex, maximum convexity near midvalve, umbonal region convex to flattened, anterior quar-

ter gently convex to nearly flat. Anterior profile narrowly convex dome with sides varying from steep to inclined medially. Beak small; umbonal region small, inflated, usually with part near beak flattened or misshapened because of close attachment to substratum. Median region usually swollen but flattened in some specimens; sides flaring and enclosing brachial valve.

Brachial valve deeply concave, defining very narrow visceral cavity. Greatest depth medially, concavity broad; sides steep; surface strongly undulated. Umbonal region deeply depressed.

Pedicle valve interior with shallow delthyrial region; sides strengthened by ridge extending from delthyrial region across ears and laterally to near anterior margin. Muscle field fairly large, occupying posterior third, anterior ends of diductor scars thickened and elevated in some specimens. Anterior region granulose.

Brachial valve with well-defined ears and long, slender, delicate septum; cardinal process bilobed in many specimens, with elongated roughened myophore. Region near distal end of septum and anterior to adductor scars strongly but sparsely endospinose.

MEASUREMENTS (in mm).—

	sur- face length	hinge width	maxi- mum width	thick- ness
USNM 727e				
153972b	30.0	37.0	6.1	17.3
(holotype)				11.2
USNM 701d				
151536a	28.9	36.0	9.3	24.0
151536b	33.0	35.0	8.5	25.8
151536c	25.4	34.0	12.0	23.8
151536d	30.3	37.0	9.4	28.2
151536e	28.4	35.0?	8.0?	18.9
151536f	26.0	30.0	7.0	24.5
151536g	29.3	37.0	?	23.3?
151536h	36.1	41.0	7.0	30.0
151536i	33.4	41.0	8.8	23.5
151536j	25.0	30.0	10.0?	21.8
151536k	27.0	30.0	10.4	26.5

STRATIGRAPHIC OCCURRENCE.—Neal Ranch and Lenox Hills formations.

LOCALITIES.—Neal Ranch: USNM 701, 701a, 701c, 701d, 715b, 721g, 727e. Lenox Hills: 705.

DIAGNOSIS.—*Striatifera* having a wide hinge and ears and with the cardinal process shaft medially indented.



**TYPES.**—Holotype: USNM 153972b. Figured paratypes: USNM 151535; 151536a, b, h; 151538a; 153923a, b; 153972a, c; 153973a-g. Measured paratypes: USNM 151536a-k. Unfigured paratypes: USNM 151536c-g, i-k; 153972b.

**COMPARISONS.**—The presence of a wide (for the genus) but well-defined hinge distinguishes this species from all other Glass Mountains striatiferiform brachiopods.

**DISCUSSION.**—The exterior expression of this species is reminiscent of *Linoproductus*. Unfortunately, few specimens are thick-shelled enough to show good impressions of the soft parts but other features of the shell are worthy of special mention. One interesting feature is the sporadic occurrence of attachment spines at any point on the body of the shell. Many specimens have spines in abundance on the umbonal slopes. Spines appear at any point where attachment seems to be advantageous, even at midvalve and on the anterior slope. Such a device permitted firm anchoring among the maze of bryozoans and algae in which the animal lived. The few specimens showing traces of the muscles indicate elongate diductor scars on the lateral slopes, and in front of them a large patch of scattered, stubby endospines. This patch is not similar to the conspicuous patch seen in *Compressoproductus curtus* from the Cathedral Mountain Formation.

Most brachial valves of this species are imperfect because of the delicate nature of the shell and because they are commonly encrusted by other organisms and break in any effort to remove them from the tangled masses in which they occur. Nevertheless, many details of anatomy were gleaned from these fragments and one old adult, the holotype. On the exterior the umbonal region has the form of a smooth swollen blister, indicating that the youngest stage of this species was biconvex and that the concavo-convex shell developed when it attained an upright position.

The cardinal process is well preserved on many specimens and exhibits an unusual feature. The median septum is long but generally low as usual. The cardinal process is located on its proximal end as a flat ridge, the shaft of the process and the septum being continuous. On its anteroventral face the shaft in most specimens is deeply indented or cleft, the slit in some specimens extending

posteriorly and visible along the myophore. In others no trace can be seen, either on the myophore or on the shaft. The youngest specimens show this lobation of the shaft, but it is likely that with age the slit is filled by adventitious shell.

The adductor scars have not been individualized in any specimen, but their position on each side of the septum near midvalve is clear in the holotype. Their anterior limit is indicated by scattered stubby endospines on the anterior slope. Many brachial valves have numerous deep pits on the posterolateral margins and sides that appear to correspond with the position of the rhizoid spines on the opposite valves. No evidence of these pits was detected on the exterior.

**ECOLOGY.**—*Striatifera linoproductiformis* is commonly found attached to fenestellid bryozoans and is also frequently the seat of attachment for these organisms. Another common member of the assemblage is *Fissispongia*. The brachiopods live intimately tangled with the bryozoans and sponges, their rhizoid spines tying them to the lacy colonies. *Striatifera* is also the host to *Pseudoleptodus*, *Diplanus*, and *Atelestegastus*. Algae also play a considerable role in this environment, growing over all of the animals regardless of their form. Many of the *Striatifera* are overgrown by formless material, now silicified, which spoils the specimens for study.

### Genus *Compressoproductus* Sarycheva, 1960

*Compressoproductus* Sarycheva, 1960:231.—Williams et al., 1965:H506.

Variable in size from small to fairly large, usually triangular to narrowly or widely oval in outline; hinge usually very narrow; shells widest anteriorly; beak usually misshapen or flattened by attachment and commonly with scar of attachment; anterior commissure usually broadly sulcate. Spines all of rhizoid or anchoring type, occurring in ring around umbo in young, and concentrated along lateral margins from beak to anterior margin; occasional scattered rhizoid spines on body and sides. Surface usually wrinkled, and in some species, fairly regularly concentrically undulated. Surface and undulations covered by radial, crowded capillae.

Pedicle valve interior with beak region usually unmodified; old shells with lateral thickenings;

muscle field apical in position; diductor scars flabellate; adductor scars not differentiated. Area anterior to muscle field usually occupied by coarse granules or stout endospines.

Brachial valve interior striatiferiform with long median septum thickened and elevated proximally to form cardinal process; septum tapering anteriorly. Cardinal process unilobate, myophore elongated, roughened. Adductor field not clearly visible, located on each side of median septum, and anteriorly bounded by roughened, granulose area or endospinose zone.

TYPE-SPECIES.—*Productus compressus* Waagen (1884: 710, pl. 81: figs. 1, 2).

DIAGNOSIS.—Triangular to oval, usually convex. Striatiferinae with capillate exterior and unmodified pedicle valve beak region.

DISCUSSION.—We were most fortunate in this study to obtain exceptional silicified material of *Compressoproductus* from many parts of the section from the Neal Ranch Formation to the late Word. Some specimens, because of their extremely thin shells, are fragmentary, but good posterior parts, from which the entire morphology may be determined, are preserved.

The exterior of this genus is distinctive. Compared to *Striatifera* it is small, even the largest species is smaller than most fully grown *Striatifera*. They are also extremely finely capillate and their abundantly undulated shells are different from *Striatifera*. We also suspect a somewhat different living habit, as mentioned below. The spines of *Compressoproductus* are usually fairly stout for such small shells, in contrast to the generally fine spines of the larger *Striatifera* shell. All species from the Glass Mountains have fairly stout spines, usually in a ring around the umbo, and a row along the lateral margins. Occasional rhizoid spines are put out from the body further to strengthen the support of the shell.

The interior details of interest in both valves center about the apical region. The beak is generally considerably reduced and is occasionally distorted by close appression to the substrate to which the shell is attached. The hinge is normally greatly narrowed, but it preserves a semblance of a straight line, and minute ears are usually formed at the extremities. Although the apex of the pedicle valve is not strengthened, the sides extending

anteriorly usually are thickened by a ridge that runs anteriorly for a short distance. The shells having the narrowest apex usually have the best development of the ridge. This ridge reaches a climax in *C. rarus*, new species, and in *C. species 5*, in both of which it overhangs the apical cavity and its proximal end terminates in a short, vertical strut.

In these species the ridge and strut have a tendency to narrow the apex and serve as an articulating device. In American *Compressoproductus* the lateral ridge is usually not well developed.

Most species of *Compressoproductus* are very thin shelled, with the result that the muscle scars are not well impressed. In fact none of the scars except the diductors of the pedicle valve have been distinguished in any detail. Were it not for the fact that several species have a thickening anterior to the muscle field, it is probable that the position of the diductors would not have been detected. Most species have, in addition to the thickening anterior to the muscle field, a strong development of thick blunt pustules that in some are large enough to attain the status of endospines.

The brachial valve interior is entirely like that of *Striatifera* and is the feature that welds these genera into a compact family. The cardinal process is uniformly an elongated expansion of the median septum which has a roughened myophore on its ventrad surface. The degree of expansion and elevation of the septum is very variable and is somewhat dependent on the form of the apical region. One specimen of *C. flabellatus*, new species, shows the proximal part of the myophore capped by a thin rounded plate which is tubular distally. At the end of the tube clear muscle impressions appear on the myophore.

ECOLOGY.—The shell of *Compressoproductus* was attached by the beak and maintained itself vertical to the substratum by the lateral and umbonal spines serving as supports and holdfasts. Specimens lived singly, attached to convenient hard objects or to other of their own kind. We have not found any locality where the specimens lived in clusters of individuals shingled together as is characteristic of *Striatifera*. The habit of *Compressoproductus* was more like that of the aulostegids such as *Agelesia* and *Institella*, with which it often occurs. The members of the genus were more inclined to live

individually rather than intimately and "colonially."

*Compressoproductus acuminatus*, new species

PLATE 462: FIGURES 9-53; PLATE 463: FIGURES 9-11

Medium size for genus, variable, elongate triangular outline, usually with fairly straight sides but with flaring anterior. Greatest width anterior to midvalve; apical angle varying between 50° and 80°, averaging about 60°. Surface very finely capillate, about 4 to 6 per mm at front of specimen of average size. Surface marked further by irregular undulations. Rhizoid spines stout, umbonal, and lateral in position.

Pedicle valve variable in lateral profile, ranging from nearly flat to moderately convex, usually with umbonal region moderately curved. Anterior profile flatly to somewhat narrowly domed and with moderately steep sides. Umbonal region narrowly

swollen but flattened at beak, small cicatrix of attachment at beak. Median region generally somewhat swollen and, in some specimens, separated from umbonal region by shallow transverse depression. Anterior slope usually gentle; sides usually steep.

Brachial valve moderately concave, deepest near midvalve; longitudinal line gently bowed but transverse section at midvalve moderately concave. Sides slightly deflected.

Pedicle valve interior without apical plates of any sort; lateral ridges poorly formed; muscle region occupying about posterior third; mid-region sparsely marked by weak but fairly large pustules.

Brachial valve interior with median septum reaching to near midvalve, there low and slender but rising posteriorly to meet narrowly expanded and strongly elevated cardinal process. Area around distal extremity of median septum coarsely pustulose.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	maximum width	height	thickness
USNM 722v							
151546a	20.4	16.0	33.0	2.8	16.4	13.7?	4.4
(holotype)							
151546b	24.4	23.0	27.0?	2.5	14.4	7.8	2.3
151546c	24.0	?	27.0	2.8	13.0	7.0	?
151546d	22.8	20.4?	26.0	2.9	18.9	7.8	2.2
151546e	20.0	?	25.0	2.5	14.0	9.1	6.0?
151546f	27.0	?	30.0	2.8	17.0	8.7?	?
151546g	29.0	?	35.0	2.8	16.5	10.0	?
151546h	20.0	?	22.0	1.5	16.5	5.0	?

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—Road Canyon: USNM 722v, 726d.

DIAGNOSIS.—Strongly acuminate, small *Compressoproductus*.

TYPES.—Holotype: USNM 151546a, Figured paratypes: USNM 151546b, c, e, f, h-k. Measured paratypes: USNM 151546b-h. Unfigured paratypes: USNM 151546d, g.

COMPARISON.—This is the smallest *Compressoproductus* occurring in the Glass Mountains and

differs from *C. parvus*, new species, in the lesser curvature, and the less concentric undulation. It is more triangular and less spreading than *C. curtus*, new species, which is also much larger and more granulose internally. It differs from *C. flabellatus*, new species, in the same features and, in addition, is triangular rather than transversely elliptical.

DISCUSSION.—The silicification of these specimens is unfortunately somewhat splotchy and the ornament is not well defined. Many specimens, however, are in position of growth and show the anchoring by the lateral rhizoid spines.

*Compressoproductus compressus* (Waagen)

PLATE 457: FIGURES 9-17

*Productus compressus* Waagen, 1884:710, pl. 81: figs. 1, 2.

Illustrations of *Compressoproductus compressus* (Waagen) are introduced for comparison with the Texas species.

TYPES.—Figured specimens: USNM 96597a, b; 153963; 153964; 153965.

*Compressoproductus concentricus*, new species

PLATE 455: FIGURES 11-23

Medium size for genus, widely oval to triangular in outline, greatest width from midvalve anteriorly, posterolateral margins nearly straight, forming angle of about 80°. Sides strongly rounded; anterior margin broadly rounded. Surface strongly undulose, undulation most prominent on sides, but discontinuous across the body of shell. Capillae numbering about 17 in 5 mm at front margin.

Pedicle valve unevenly convex in lateral profile, maximum curvature near midvalve, posterior and anterior portions somewhat flattened. Anterior profile broadly domed and with moderately steep sides. Umbonal region short, expanding rapidly and with steep slopes. Median region swollen but anterior slope long and moderately steep. Sides not flaring.

Brachial valve moderately concave and bounding fairly deep visceral cavity at or near midvalve.

Interior of both valves unknown.

MEASUREMENTS (in mm).—

	length	surface length	width	height	thickness
USNM 714t					
151575a	31.6	39.0	32.2	10.0?	?
(holotype)					
151575b	43.2	53.0	39.0	19.0	?
151575c	?	?	?		8.0

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch Member), Hess Formation (Taylor Ranch Member).

LOCALITIES.—Decie Ranch: USNM 707a, 714t; Taylor Ranch: 716o.

DIAGNOSIS.—Laterally expanding *Compressoproductus* with fairly regular concentric wrinkles.

TYPES.—Holotype: USNM 151575a. Figured paratypes: USNM 151542, 151575b. Measured para-

types: USNM 151575b, c. Unfigured paratype: USNM 151575c.

COMPARISON.—This species is short and wide, therefore suggesting *C. curtus*, new species, but differing in its stronger and more regular concentric wrinkles. The spreading outline of this species separates it from *C. thomasi* and *C. rarus*, both new, and *C. pinniformis* (Girty). It is much larger and much differently ornamented than *C. parvus*, new species.

DISCUSSION.—This is a rare species and the sample resulted from the breaking of an enormous quantity of rock while searching for *Scacchinella* and *Geyerella* at USNM 707a and 714t. Twelve specimens were found but only four of them are of good quality.

*Compressoproductus curtus*, new species

PLATE 460: FIGURES 9-39

Widely triangular in outline, but variable; widest from midvalve anteriorly; posterolateral margins nearly straight to moderately concave, anterior margin usually broadly curved. Apical angle variable, ranging from 70° to 85°. Surface capillate and undulose, capillae numbering about 20 in 5 mm at front of specimen about 30 mm long; undulations concentric, moderately strong, closely crowded, discontinuous laterally.

Pedicle valve unevenly but not strongly convex in lateral profile, maximum convexity near midvalve, with posterior flattened and anterior flattened to slightly concave. Anterior profile broadly domed, sides sloping moderately to steeply. Umbonal region narrowly convex, not elongated. Median region swollen, with long and moderate slopes to sides and anterior.

Brachial valve deeply concave, sides steep posteriorly but less steep anteriorly.

Pedicle valve interior with lateral margins thickened; diductors laterally placed, small, oval, with thickened margins rarely slightly elevated. Adductor scars not visible; endospines thick and large in patch just anterior to muscle field.

Brachial valve interior with thick, long cardinal process, large adductor field divided by delicate median septum, endospines large and thick in patch at anterior end of median septum.

## MEASUREMENTS (in mm).—

	length	surface length	width	height	thickness
USNM 702b					
151569	26.0	30.0	29.2	13.6	3.2
(holotype)					
151568b	23.9	34.0	29.0	13.0	?
151568c	22.2	34.0	30.0	15.0	?
151568d	27.1	39.0	23.4	13.2	?
151568e	32.3	39.0	32.0	12.4	?
151568f	37.5	45.0	34.0	12.4	?
151568g	36.3	52.0	34.8	15.0	?
151568h	26.3	35.0	25.0	9.5	?
151568i	22.2	28.0	20.0	10.0	?
151568j	22.8	29.0	21.0	12.3	?
151568k	23.7	30.0	19.9	8.9	?

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITIES.—AMNH 500L; USNM 702b, 702ent, 702 low, 703b, 703bs, 726y, 727o.

DIAGNOSIS.—Short and wide *Compressoproductus* having a patch of thick endospines around the front margin of the muscle field.

TYPES.—Holotype: USNM 151569. Figured paratypes: USNM 151568a, e-g, m, n. Measured paratypes: USNM 151568b-k. Unfigured paratypes: USNM 151568b-d, h-l.

COMPARISONS.—This species is distinguished from all others in the Glass Mountains by its considerable width in relation to the length, and the fairly great height of the pedicle valve. No other Glass Mountains species except *C. flabellatus*, new species, has the strong development of endospines in the pedicle valve.

DISCUSSION.—Internal features are usually not easy to obtain in this group of thin-shelled brachiopods. Consequently, the total anatomy must be synthesized from a study of all the species that can be obtained. The particular feature of interest in this species is the development of a patch of large endospines anterior to the muscle field. The patch is confined to a small region near the point of maximum concavity. The endospines appear to guard the area occupied by the viscera.

A specimen referred to this species, measuring 9 mm in both length and width, is remarkable both for a moderately wide hinge region and the retention of a small attachment ring on the umbonal region. The attachment surface was evidently thin because it was badly torn when the specimen broke from its moorings. The beak is misshapen and the ring is made of two spines. Anchor spines appear

along the posterior margin on each side of the umbonal region. The shell is only slightly convex.

*Compressoproductus flabellatus*, new species

PLATE 456: FIGURES 22–50; PLATE 461: FIGURES 1–66; PLATE 464: FIGURES 24–26

*Striatifera pinniformis* R. E. King (not Girty), 1931:78, pl. 17: figs. 16–19.

Small for genus, transversely but roundly elliptical in outline, maximum width near midvalve; sides strongly and narrowly rounded and anterior margin broadly rounded to truncated. Umbonal region short and narrow. Pedicle valve usually shallow. Apical angle usually greater than right angle. Surface with regular concentric undulations, strongest on sides, but extending over the whole shell except for anterior margin; capillae very fine and delicate, numbering 5 or 6 per mm.

Pedicle valve varying from nearly flat to fairly strongly rounded in lateral profile but usually gently and unevenly rounded, posterior half somewhat flattened but anterior moderately rounded. Anterior profile broad, moderately convex evenly rounded dome. Umbonal region narrowly swollen but not usually strongly differentiated. Posterior half of pedicle valve generally flattened but anterior half moderately swollen to produce short, steep anterior slope; lateral slopes fairly steep.

Brachial valve represented only by fragmentary specimens.

Pedicle valve interior with incurved minute beak, hinge extremities with minute ears; lateral ridges moderately developed; muscle scars not well differentiated but with thickened anterior border. Region anterior to muscle scars marked by thick granules or stubby endospines.

Brachial valve interior with long slender median septum passing proximally into high cardinal process with narrow but long myophore.

MEASUREMENTS (in mm).—Brachial valve length, and thickness, unmeasurable.

	length	surface length	hinge width	mid- width	height
USNM 721u					
152788a	18.6	23.0	3.7	19.2	9.7
(holotype)					
152788b	19.2	22.0	3.9	22.3	5.2
152788c	15.2	19.0	8.7	17.8	5.5
152788d	16.4	19.0	6.4	16.3	5.0
152788e	18.8	23.0	3.9	21.2	6.5
152788f	16.6	23.0	5.0	20.8	8.7



STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation.

LOCALITIES.—USNM 712o, 721u, 726u.

DIAGNOSIS.—Roundly and transversely elliptical *Compressoproductus*.

TYPES.—Holotype: USNM 152788a. Figured paratypes: USNM 152788b–f, h, j–p, s, t; 153960a–g. Measured paratypes: USNM 152788b–f. Unfigured paratypes: USNM 152788g, i, q, r. Figured specimen: YPM 11634.

COMPARISON.—This species resembles two others: *C. acuminatus* and *C. curtus*, both new. It differs from the former by its transversely elliptical outline, less elongated posterior, and more expanded anterior region. It suggests *C. curtus* because that species is strongly granulose anterior to the muscle field in the pedicle valve and because the form of the adults is similar. *Compressoproductus curtus*, however, is much larger and its young stage is different from that of *C. flabellatus*. The young of *C. curtus* are rather narrowly elongated whereas *C. flabellatus* is subcircular or transverse in youth and throughout life.

King's specimen identified as *Striatifera pinniformis* Girty rather suggests *C. flabellatus* than it does Girty's species, which comes from the Capitan Limestone. King's (1931) figure 18 may represent the same species, since it is from the same stratigraphic level.

DISCUSSION.—This is a variable little species having deep and shallow forms, subcircular ones, and rarely an occasional triangular specimen. The hinge varies considerably, probably dependent upon the nature of the object to which it was attached. Although we have a fair supply of pedicle valves, only three brachial valves were taken. One of these is aberrant in having the proximal end covered by a convex plate which is slightly tubular anteriorly. The muscles were attached to the part of the myophore just anterior to the tube.

*Compressoproductus parvus*, new species

PLATE 459: FIGURES 9–31

Small, oval in outline, posterolateral margins straight or slightly concave; sides gently rounded, anterior margin narrowly rounded. Apical angle about 70°. Surface finely capillate and undulated. Capillae numbering about 17 to 20 per 5 mm at front of large specimen. Concentric undulations

numerous, strong, and in some specimens crossed by oblique undulations to produce quincuncial pattern.

Pedicle valve with variable lateral profile, usually moderately convex with maximum curvature at or near middle, posterior third moderately convex, rarely concave, anterior third usually gently convex but some specimens with narrowed concave band at anterior. Umbonal region short, narrowly convex. Median region swollen; sides steep and broadly expanded when seen from side.

Brachial valve deeply concave, fitting pedicle valve closely; deepest in midregion and with steeply sloping sides. Concentric undulations strong.

Interior unknown.

MEASUREMENTS (in mm).—

	length	surface length	width	height	thickness
USNM 708e					
151560a	33.4	43.0	26.2	14.1	?
(holotype)					
151560b	26.5	39.0	21.2	12.7	?
151560c	30.1	41.0	25.6	13.6	?
151560d	20.6	24.0	17.0	8.8	3.0
151560e	27.0	34.0	19.0	12.0	?
151560f	19.5	30.0	19.1	12.4	2.3
151560g	25.5	19.0	19.0	11.0	?
151560h	21.7	26.0	19.6	7.6?	3.0

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch, Poplar Tank, Dugout Mountain, and Sullivan Peak members).

LOCALITIES.—Decie Ranch: USNM 707g. Poplar Tank: USNM 708e. Dugout Mountain: USNM 733–1. Sullivan Peak: USNM 707d, 715f, 715j, 717a, 722–1, 722m, 727a. Skinner Ranch: USNM 723–1, 730o, 730s.

DIAGNOSIS.—Small, irregularly wrinkled *Compressoproductus*.

TYPES.—Holotype: USNM 151560a. Figured paratypes: USNM 151545; 151560b, c, h; 153968. Measured paratypes: USNM 151560b–h. Unfigured paratypes: USNM 151560d–g.

COMPARISONS.—In size this species suggests *C. pinniformis* (Girty) but it is not so attenuate and has a more strongly curved lateral profile than the Guadalupe Mountains species. Furthermore, it is ornamented differently from *C. pinniformis*, which has broad undulations. *Compressoproductus parvus* is one of the smaller species from the Glass Mountains. Besides this feature it is distinguished from all but one of the Glass Mountains species of

*Compressoproductus* by its peculiar ornament, which is like that of *C. thomasi*, new species. The latter, however, is a much larger species and has a much less curved lateral profile.

***Compressoproductus pinniformis* (Girty)**

PLATE 464: FIGURES 1-23

*Productus pinniformis* Girty, 1909:273, pl. 12: figs. 5, a, b. [Not *Striatifera pinniformis* R. E. King, 1931:78, pl. 13: figs. 16, 17 (= *Compressoproductus thomasi*, new species); not figs. 18, 19 = ?.]

Small to medium size for genus, outline forming elongated triangle; variable and frequently distorted. Sides gently concave; anterolateral extremities broadly rounded; anterior margin broadly rounded to medially emarginate. Beak narrow, forming angle in majority of specimens of about 70°, but variable. Surface capillate to finely costellate, number of capillae or costellae in 5 mm at front of large individual, ranging from 16 to 20. Concentric wrinkles broad and irregular, extending from beak to anterior margin.

Pedicle valve forming broad gentle curve in lateral profile, posterior half generally slightly more convex; anterior profile forming narrow, steep-sided, smooth-topped dome. Beak small; umbonal region narrow, commonly elongated. Median region somewhat narrowly swollen. Sides steep posteriorly concave, becoming convex anterolaterally.

Brachial valve fitting pedicle valve closely, broadly and deeply concave in median region, sides sloping moderately toward midvalve.

Interior not known.

STRATIGRAPHIC OCCURRENCE.—Capitan Formation.

LOCALITIES.—USGS 2926 (green); USNM 737a, 750, 750b.

DIAGNOSIS.—Small and median elongate and attenuate *Compressoproductus* with gentle to moderately curved lateral profile and moderately expanded anterior.

TYPES.—Holotype: USNM 118541. Figured hypotypes: USNM 151526b-e, q; 153961a-c. Measured hypotypes: USNM 151526a-r.

COMPARISONS.—The broad and sparse undulations separate this species from *C. thomasi* and *C. parvus*, both new, which have elaborate intersecting sets of undulations. It is much more elongate and

MEASUREMENTS (in mm).—

	length	surface length	width	height	thickness
USGS 2926					
118541	20.0	23.0	15.0	5.4	?
(holotype)					
USNM 750					
151526a	38.7	47.0	28.6	15.0?	?
151526b	36.3	39.0	30.7	16.0?	?
151526c	33.8	40.0	21.0	10.3?	?
151526d	33.6?	41.1?	24.0	16.0?	?
151526e	27.0	30.0	23.2	14.0	?
151526f	25.6	25.0	23.3	14.4	?
151526g	32.0	40.0	20.5	15.6?	?
151526h	28.3	32.0	21.8	13.4	?
151526i	28.2	33.0	19.4	13.3	?
151526j	23.0	21.0	17.0	7.5	?
151526k	20.0	24.0	15.6	7.5	?
151526l	21.7	26.0	15.0	7.4	?
151526m	19.4	21.0	15.0	5.2	?
151526n	17.3	20.0	16.7	7.7	?
151526o	16.8	16.0	13.8	5.0	?
151526p	13.4	15.0	11.3	4.6	?
151526q	8.8	8.5	6.9	3.0	?
151526r	26.4	29.0	22.3	9.0	4.0

attenuate than *C. curtus*, new species. It has some resemblance to *C. rarus*, new species, but does not attain the large size of that species and is not so strongly wrinkled. The well-defined hinge region of *Striatifera linoproductiformis*, new species, is strikingly different when compared with the narrow beak and umbonal region of the Guadalupe species.

***Compressoproductus rarus*, new species**

PLATE 457: FIGURES 18-22; PLATE 458: FIGURES 1-39; PLATE 459: FIGURES 32-34

Large, elongate-oval outline, posterolateral margins straight, sides strongly rounded and anterior margin narrowly rounded. Apical angle about 70°. Surface with fairly regular strong undulations, concentrated on sides. Surface undulations covered by capillae numbering about 15 per 5 mm at front margin of holotype.

Pedicle valve in lateral profile forming broad curve, strongest slightly posterior to midvalve, posteriormost part near umbonal region flattened. Anterior profile strongly domed and with steep sides. Umbonal region short, narrowly pinched but

swelling rapidly anteriorly to join swollen median region. Umbonal slopes long and steep; anterior slope long, moderately steep. Delicate rhizoid spines clustered on posterolateral extremities, more scattered anteriorly along lateral margin.

Brachial valve incompletely known but with narrow concave umbonal region.

Pedicle valve interior with strongly thickened posterolateral margins buttressed by short discrete plates at the apex; diductor scars small, marginal; region anterior to muscle field strongly granulose and with prominent endospines.

Brachial valve with low median septum strongly elevated at cardinal process which is elongate, narrow, but with long roughened myophore and long lophidium.

MEASUREMENTS (in mm).—

	length	surface length	width	height	thickness
USNM 706c					
151566a	51.0	62.0	40.0	19.3	?
(holotype)					
151566b	32.8	39.0	26.4	11.0	?
151566c	32.7	42.0	24.2	15.2	?
151566d	27.1	28.0	23.8	9.6	?
151566e	29.6	32.0	24.7	11.8	?
151566f	16.5	17.0	13.7	5.6	?
151566g	42.8	52.0	38.0?	15.4	?
151566h	24.2	27.0	21.4	7.8	?

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank Member and lens between Willis Ranch and Appel Ranch members).

LOCALITIES.—Word: USNM 732s. China Tank: 706c, 733q. Lens: 706b.

DIAGNOSIS.—Large, moderately convex wrinkled *Compressoproductus*.

TYPES.—Holotype: USNM 151566a. Figured paratypes: USNM 151564; 151565a, b; 151566b–h, k; 153966; 153967. Measured paratypes: USNM 151566b–h. Unfigured paratypes: USNM 151566i, j.

COMPARISONS.—This species, the largest of the genus in the Glass Mountains, has a fairly thick shell. Its nearest competitor in size is *C. thomasi*, new species, which is more rounded in anterior profile, less attenuate at the beak, and marked by two sets of wrinkles that cross at an angle. Young specimens of *C. rarus* suggest *C. pinniformis* (Girty) because of their strongly attenuate beaks and

umbonal regions, but *C. rarus* is more strongly and regularly wrinkled and more strongly capillate.

### *Compressoproductus thomasi*, new species

PLATE 454: FIGURES 1–22; PLATE 455: FIGURES 3–10; PLATE 457: FIGURES 1–8

*Striatifera pinniformis* R. E. King (not Girty), 1931:78, pl. 17: figs. 16, 17.

Large, elongate triangular in outline, apical angle about 70°. Sides unevenly and gently convex, bulging slightly medially. Anterior margin narrowly rounded. Surface finely capillate and strongly undulated; capillae of unequal size, numbering about 17 to 20 per 5 mm near front of large specimen. Concentric undulations strong, in posterior third fairly regular but in anterior two-thirds becoming irregular and crossing with oblique undulations from sides to make pronounced chevron pattern in some specimens. Rhizoid spines slender, long, concentrated on posterolateral extremities and sides.

Pedicle valve unevenly convex in lateral profile, most convexity at or near midvalve, posterior part gently curved or slightly flattened, anterior quarter with gentle concavity. Anterior profile forming rounded dome with sides steep or sloping medially to form incomplete tube. Beak minute, umbonal region narrowly convex, expanding rapidly to join much inflated median region. Sides steep not greatly flattened or flaring. Anterior margin flattened and slightly reflected in ventral direction in anterior quarter.

Brachial valve closely fitting into pedicle valve and forming very narrowly restricted body cavity, maximum concavity near midvalve; sides moderately steep. Surface undulated as in opposite valve.

Pedicle valve interior with marginally thickened posterior; thickening extending along and strengthening margin to place of widening just posterior to midvalve. Muscle marks not visible.

Brachial valve interior with median septum low, thin ridge terminating posteriorly in cardinal process; adductor impressions not clear; cardinal process with long slender shaft bearing thickened ridge, roughened at distal extremity for attachment of muscles, but with low, rounded lophidium at proximal end.

MEASUREMENT: (in mm).—

	length	surface length	width	height	thickness
USNM 708					
151552a (holotype)	52.5	61.0	34.0	20.0?	?
151552b	37.0	45.0	27.3	13.7	?
151552c	47.4	55.0	33.0	17.8	?
151552d	45.0?	51.0?	33.7	14.0	?
151552e	28.3	35.0	25.6?	8.0	3.6
151552f	22.8	25.0	25.4	9.6	?
151552g	26.0	31.0	27.0	8.4	?

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation (Wedin Member).

LOCALITIES.—Cathedral Mountain: USNM 702, 702un, 703b, 703bs, 708, 712o, 721u, 727q, 730q, 731n. Wedin: Moore 23; USNM 714w, 717e, 723v, 727p, 700-1, 700x.

DIAGNOSIS.—Large *Compressoproductus* with crisscross undulations.

TYPES.—Holotype: USNM 151552a. Figured paratypes: USNM 151552c, e, h; 151554a, b; 153954a-d; 153955a-c; 153956; 153962. Measured paratypes: USNM 151552b-g. Unfigured paratypes: USNM 151552b, d, f, g.

COMPARISONS.—This is the next to largest of the species of this genus in the Glass Mountains, the largest being *C. rarus*, new species. The crisscross undulations and subcylindrical anterior profile of *C. thomasi*, new species, readily distinguished it from *C. rarus*, new species, and most other American species of *Compressoproductus*. A species ornamented like *C. thomasi* is *C. parvus*, new species, but it is so much smaller and differently shaped that the two are not likely to be confused.

DISCUSSION.—Several specimens in the collection show the strong attachment spines and the means of attachment of the shell. The spines are mainly confined to the margins and are usually long where necessary. Body spines are rare. The species is named for G. A. Thomas, University of Melbourne, Australia, in recognition of his work in Permian brachiopods.

### *Compressoproductus* species 1

PLATE 456: FIGURES 1-21

This is a highly variable species having the triangular form characteristic of the genus; it is finely capillate and moderately wrinkled. One

specimen (USNM 153959d) is large and abruptly expanded but the other pedicle valves are more triangular and only moderately rounded anteriorly. The brachial valves have a well-developed median septum and narrow myophore and are not unusual in any way.

This species suggests *C. parvus*, new species, but it is much smaller. It is much more narrowly elongated than either *C. curtus* and *C. flabellatus*.

Figured specimens: USNM 153959a-h.

STRATIGRAPHIC OCCURRENCE AND LOCALITY.—Road Canyon Formation: USNM 726d.

### *Compressoproductus* species 2

Small, oval in outline, with rounded sides and narrowly curved front margin. The apical angle is near 80°. The specimen is undulose and capillate, having 10 capillae in 2 mm. The pedicle valve has an even and gentle curve in lateral profile; the anterior profile narrowly domed and steep-sided.

Described specimen: USNM 151577.

MEASUREMENTS (in mm).—Length 18.9, surface length 22.0, maximum width 15.0, height 7.8.

STRATIGRAPHIC OCCURRENCE AND LOCALITY.—Word Formation (lens between Willis Ranch and Appel Ranch members): USNM 706b.

### *Compressoproductus* species 3

PLATE 433: FIGURES 1-5

Small and widely triangular in outline, this species is nearly flat in lateral profile. The anterior profile is also nearly flat except for the sides which are abruptly bent and precipitous. The sides are nearly straight and diverge at about 85°. Antero-lateral extremities narrowly rounded and anterior margin broadly curved. The surface is marked by close and small undulations, the whole being covered by delicate capillae, barely discernible but not clear enough to be counted in the one specimen. Stout spines are clustered on each posterolateral margin.

Figured specimen: USNM 151578.

MEASUREMENTS (in mm).—Length 25.4, surface length 26.5, maximum width 27.1, height 10.0, thickness unknown.

STRATIGRAPHIC OCCURRENCE AND LOCALITY.—Road Canyon Formation at USNM 703a.

*Compressoproductus* species 4

PLATE 433: FIGURES 6-18; PLATE 455: FIGURES 24-28

Only fragments or very young specimens of this species from the Skinner Ranch Formation are available for study. A species of more than 30 mm length and 25 mm width is indicated by the largest piece, which is complete except for part of the anterior margin. The external markings are similar to those of all other species of the Glass Mountains with interrupted undulations best developed on the sides and capillae numbering 6 to 8 in 2 mm at the anterior margin. The apical angle is about 75°, the posterolateral margins are nearly straight, but the sides are curved and the anterior margin probably broadly curved. The height is about 10 mm. The posterior has a narrow hinge about 3.5 mm wide but the beak is obscured by attachment apparatus. The brachial valve, preserved only as fragments of the posterior, nevertheless shows the internal structures to perfection. The great value of these specimens is the information they afford on the attachment and development of the pedicle valve.

The shape and means of attachment of the young *Compressoproductus* are wholly dependent on the nature of the surface to which the larva adheres after settling. If the animal settles on a flat surface the attachment face, or cicatrix, is broad and flat and usually has a series of spines that creep out onto the surface to help in anchoring. On the other hand, if the spat settles on a round object such as another productid spine or bryozoan, the umbonal region may be grooved and the anchoring spines wrap around the supporting surface. The latter means of attachment is a common one. A common feature of the young of this species is a broad, cushionlike expansion on the beak which sends out spines laterally. Early attachment spines are commonly much larger than the later ones and are usually quite thick. Depending on the orientation of the specimen on a round surface, a well-defined attachment ring may be formed. Specimen USNM 151579a was attached to a round object so that its long axis was parallel to that of the surface. In this case a single well-defined ring was formed. Specimen USNM 151579b settled with its long axis at an angle to the long axis of the cylindrical object of attachment. This attachment is a series of rings at an angle across the umbo. One of the really choice specimens (USNM 151579c) is a cluster of

four young individuals attached to each other by a tangle of spines.

The form of the earliest pedicle valve is a low circle surrounded by a ring of spines. Growth takes place on the anterior margin and sides. The initial circle becomes misshapen but is generally retained as a round cicatrix, or patch, with callosity on the posterior side representing the initial cementation of the beak.

The smallest brachial valve in the collection (USNM 151579d) is slightly over 2 mm in length. Seen from the inside, it is deeply concave in the posterior, indicating that the earliest stage of the *Compressoproductus* was biconvex, a small circular mound attached to a hard object. Concavity of the exterior developed early in its history. The cardinal process at this 2-mm stage is like that of the adult and gives no suggestion of a bilobed or trilobed ancestry. On each side of the cardinal process and about halfway to the lateral extremities a longitudinal ridge is developed. This is highest at the posterior margin and extends anteriorly, but soon dies out. These ridges, which are essentially knobs on the posterior margin, appear to be of use in articulating the shell. They are also visible in more adult brachial valves but are proportionally less conspicuous.

The cardinal process is strongly elevated at the posterior and appears as a roughened ridge in its distal part. Proximally the roughened area is covered by a smooth, sheathlike structure best homologized with the lophidium. The roughened myophore in some specimens appears to be divisible into two slender lateral scars and a broader median one.

Figured specimens: USNM 151579a-d, 153932 a-e.

STRATIGRAPHIC OCCURRENCE AND LOCALITY.—Skinner Ranch Formation (Poplar Tank Member): USNM 707ha.

*Compressoproductus* species 5

PLATE 459: FIGURES 1-8

Species 5 consists of three specimens, two pedicle valves and a fragmentary brachial valve. A single variable species, or perhaps two species, are indicated by the pedicle valves. One specimen (USNM 151567a) is nearly complete and is somewhat elliptical in outline, narrowing posteriorly and anteriorly.



only. The anterior narrowing produces a strongly nasute margin. Internally the apex of the specimen is marked by vertical struts like those seen in *C. rarus*, new species. The diductors are strongly lateral in position and have strong anterior thickenings. This specimen is 40 mm long by 29 mm wide at midvalve where it is widest. It is 19 mm deep, thus it has a strongly rounded cross section.

The second pedicle valve (USNM 151567b) is opposite to the preceding in form, as it has a narrow beak but a widely flaring anterior. It is not complete but its length must have been about 40 mm. The width based on the half measure would be about 42 mm. Most other details are obscured.

The third specimen (USNM 151567c) is a fragmentary brachial valve showing a stout median septum extending probably to midvalve. The cardinal process is high and stout and hangs slightly over the septum distally. The flattened area on each side of the septum suggests the adductor field.

Figured specimens: USNM 151567a-c.

STRATIGRAPHIC OCCURRENCE AND LOCALITY.—Hess Formation (Taylor Ranch Member): USNM 702d.

### *Compressoproductus* species 6

PLATE 460: FIGURES 1-8; PLATE 463: FIGURES 12, 13

The best preserved specimen in the lot is a widely triangular pedicle valve with a small brush of spines on the postero-umbonal slopes. Associated with it are a number of immature ventral valves and a brachial valve. Other specimens indicate a highly variable, often narrowly triangular species possibly related to *Compressoproductus* species 1.

Figured specimens: 153969a-e.

STRATIGRAPHIC OCCURRENCE AND LOCALITY.—Road Canyon Formation: USNM 721j.

Inasmuch as USNM 721j and 726d are dead-shell assemblages, it is possible that more than one species of *Compressoproductus* have been swept together. This would account for the high variability of the specimens.

### Uncertain and Misidentified PRODUCTACEA

#### *Rugoclostus semistriatus* (Meek)

PLATE 476: FIGURES 32-35

*Productus semistriatus* Meek, 1860:309; 1876:349, pl. 1: figs. 7a, b; 1877:74, pl. 7: figs. 8, 8a.—Girty, 1920:651, pl. 53.

fig. 7. [Not *P. semistriatus* R. E. King, 1931:74, pl. 15: figs. 6-11 (= *Nudauris reticulata*, new species).]

This species has been widely identified in the Permian but it actually belongs in the Early Pennsylvanian. The type species is being studied by Dr. MacKenzie Gordon whom we follow in assigning it to the genus *Rugoclostus* Easton. This genus is characterized by a long slender outline, with long trail. It has the appearance of *Inflatia* but has a different spine arrangement, spines on the brachial valve, and a general obsolescence of the fine ribbing on the anterior part of the trail. *Rugoclostus semistriatus* has not been recognized in the Permian.

TYPES.—USNM 652a-d.

STRATIGRAPHIC OCCURRENCE.—Probably Manning Canyon Shale, according to Dr. M. Gordon.

LOCALITY.—Timpanogos Canyon, southeast of Salt Lake, Utah.

#### *"Marginifera" cristobalensis* R. E. King (not Girty)

*Marginifera cristobalensis* R. E. King, 1931:86, pl. 21: figs. 19-21. [Not *Marginifera? cristobalensis* Girty, in Lee and Girty, 1909:65, pl. 7: fig. 2.]

These are very poorly preserved pedicle valves with few features on the exterior. They are nearly smooth except for spine bases which are scattered widely over the surface and appear on all parts of the shell, including the posterior margin and the umbonal slopes. The specimens suggest a small *Echinauris* so common in many parts of the Cathedral Mountain Formation, as at Split Tank and USNM 702c. They are not related to *Marginifera*. This species appears frequently in King's lists but the correct genus and species usually cannot be ascertained.

### Suborder CHONETIDINA Muir-Wood, 1955

#### Superfamily CHONETACEA Bronn, 1862

#### Family RUGOCHONETIDAE Muir-Wood

[Ex Rugosochonetinae Muir-Wood, 1962]

Muir-Wood's subfamily Rugosochonetinae is here elevated to family rank. The interior structure of these Upper Paleozoic shells is in marked contrast to that of many of the earlier genera especially in the nature of the cardinal process; the Upper Paleozoic genera have a deeply excavated antron whereas the others have a more bosslike structure.

DISCUSSION.—The family Chonetidae Bronn (1862), as conceived by Muir-Wood, contains eight subfamilies, several of striking contrast in structure. The Anopliinae, with its prominent lateral septa, is unique and deserves family rank. The cardinal processes of the Chonetinae, Strophochonetinae, Devonochonetinae, and Retichonetinae are boss-like, often with an alveolus, but are not like that of the Rugosochonetinae. The above named subfamilies can well remain under the family Chonetidae.

The subfamily Semenewiinae, because of its unusual exterior, deserves family status.

The Rugosochonetinae and Chonetellinae are related in the form and development of the visceral region and the cardinal process. The process, with its deep alveolus that forms a tentlike structure with the fused elements of the myophore, suggests the sowerbyelloid cardinal process of the Plectambonitacea. To the above families is also added the Plicochonetinae Sokolskaya (1960). Reconstituted to include *Plicochonetes* and *Rugaria*, the subfamily now has a much different constitution from its original definition.

#### Subfamily RUGOSOCHONETINAE Muir-Wood, 1962

Small to moderately large, wider than long, smooth to costellate, usually with ventral sulcus; spine row oblique; chilidium and pseudodeltidium usually present. Pedicle valve interior with short, posteromedian septum and low, often spinose, anterior ridge; surface strongly papillose. Brachial valve interior with deep alveolus, usually well developed, anteridia often protuberant; median septum long; lateral regions usually strongly endospinose.

Genera in West Texas: *Sulcataria* Cooper and Grant, 1969; *Dyoros* (*Dyoros*) Stehli, 1954; *Dyoros* (*Lissosia*), new subgenus; *Dyoros* (*Tetragonetes*), new subgenus; *Lissochonetes* Dunbar and Condra, 1932; *Eolissochonetes* Hoare, 1960; *Mesolobus* Dunbar and Condra, 1932; *Leurosina*, new genus; *Quadrochonetes* Stehli, 1954; and *Neochonetes* Muir-Wood, 1962.

DISCUSSION.—Sokolskaya (1960:222) proposed the subfamily Plicochonetinae but with an odd assortment of genera: *Waagenites* and *Longispina*. Evidently these were associated because they have the common external character of strong costation. Muir-Wood (1962:32) declined to recognize Sokol-

skaya's family and assigned its genera to other families. *Plicochonetes* was placed in her new subfamily Rugosochonetinae, but it is not at home there and is better restored to the Plicochonetinae, although not with the same associates assigned by Sokolskaya.

The Rugosochonetinae, minus *Plicochonetes*, is externally smooth to finely costellate, usually much wider than long, often with the hinge forming the widest part. A feature of the interior characterizing the Permian members of the family is the great development of endospinosity in the mediolateral areas. These are often greatly thickened and form a lateral spiny barrier along the margin. Endospines are elaborately developed in several species from the Road Canyon Formation especially *Dyoros* (*Dyoros*) *transversus* (new species). Spines appear in the pedicle valve as well as the brachial valve of this species.

Most of the chonetid genera of the Permian of the Glass Mountains, Guadalupe Mountains, and Sierra Diablo belong in the Rugosochonetinae.

Because of its strong resemblance internally to *Dyoros* (*Dyoros*) and *Rugosochonetes*, the genus *Neochonetes* is here transferred from the Chonetinellinae to the Rugosochonetinae. In every feature except the costellate exterior the two genera are almost identical. In fact some species of *Dyoros* (*Dyoros*) have sporadic costellae.

#### Genus *Sulcataria* Cooper and Grant, 1969

*Sulcataria* Cooper and Grant 1969:5.

Medium-sized to small, widely rectangular, hinge usually widest part, but variable and may be narrower than midwidth; cardinal extremities ranging from acute to slightly obtuse. Sides straight and slightly oblique to moderately rounded. Anterior margin truncated to moderately emarginate. Anterior commissure with fairly strong dorsad wave. Pedicle valve with deep sulcus bordered by fairly strong plications; fold narrow and strong. Posterior margin with short oblique spines. Pseudodeltidium a narrow rim; cardinal process with strong chilidium. Exterior smooth, falsely striate when abraded.

Pedicle valve interior with thick apical callosity and short, strong septum; median ridge extending from septum to midvalve low and inconspicuous. Diductor scars narrow, divergent and deeply impressed. Teeth large, interarea short. Lateral mar-

gins flattened to form finely granulose border. Inner lateral slopes coarsely granulose.

Brachial valve interior with large deeply excavated cardinal process; prosocket ridges moderately developed, slightly oblique, adductor dividing ridges long and slender; anderidium not conspicuous. Brevisseptum originating anterior to antron but in some specimens extending, by secondary deposition, as a ridge posteriorly into antron; brevisseptum distally elevated and forming angular crest with long, commonly spinose anterior slope. Anteromedian trough deep; anterolateral extremities of visceral region strongly thickened and elevated, surrounded by finely granulose flattened border laterally.

TYPE-SPECIES.—*Chonetina?* *rostrata* Dunbar and Condra (1932:150, pl. 19: fig. 1).

DIAGNOSIS.—Smooth, strongly sulcate Chonetacea with anterolaterally thickened visceral region and deep anteromedian trough in the brachial valve.

COMPARISONS.—This genus is essentially a smooth *Chonetinella* Ramsbottom, and therefore need be compared only to the smooth genera. It is unlike *Dyros* (*Dyros*) in the widely expanding sulcus and the much less extended hinge which is not prolonged into sharp points or ears as in *Dyros* (*Dyros*). Internally *Dyros* (*Dyros*) does not have the flattened marginal rim in both valves so common in *Sulcataria*, and it is not provided with the narrow and deep anteromedian trough so characteristic of *Sulcataria*.

Many features of *Sulcataria* relate it to *Leurosina*, new genus, especially the details of the interior. The two are quite unlike externally as *Leurosina* is only gently sulcate on the pedicle valve and the dorsal valve has the margin reflected and does not have a strong fold like that of *Sulcataria*.

The strong folding of the exterior and the strong development of the brachial valve interior with its elevated anterolateral portion of the visceral region and the deep anteromedian trough distinguish *Sulcataria* from *Lissochonetes* Dunbar and Condra.

The wide folding of *Quadrochonetes* Stehli and the lack of folding and totally different interior of *Tornquistia* Paeckelmann are sufficient to distinguish these two smooth genera from *Sulcataria*.

DISCUSSION.—The form and structure of this genus are like those of *Chonetinella*. Indeed, it was originally described as *Chonetina?* and is essentially a smooth *Chonetinella*. This is definitely a smooth

shell when well preserved but many of the specimens were collected loose on shale banks, where they have been exposed to the weather, with the result that the thin smooth outer layer has been eroded away to expose a fine inner striation which is undoubtedly connected with the radial arrangement of the taleolae. Dunbar and Condra (1932) described the type species as a radiate shell. Ralph H. King (1938) referred his species *primitiva* to *Chonetina* with a query as did Dunbar and Condra their species *rostrata*. King regarded his species as "lirate" and noted that the lirae were faint apically, but stronger anteriorly. Metatypes of King's species show the shell to be smooth in protected parts especially in the posterior part of the brachial valve. Well preserved specimens of Dunbar and Condra's *C.?* *rostrata* are also smooth where unweathered. A similar appearing but undescribed species from the Graford Formation (Wolf Mountain Shale) (R. H. King 1938:265) is also smooth externally.

The pits displayed by many specimens are another conspicuous feature of these shells; they indicate the position of minute spines that must have covered the shells in life. These pits are arranged radially and are alternate in opposite rows. Other undescribed species from the Gonzales, Jacksboro, and Finis members of the Graham Formation show these spine pits to perfection.

The known species of *Sulcataria* and an undescribed species from the Pennsylvanian (Graford Formation, Wolf Mountain Shale Member) have strongly marked interior details. The septal portion of the median ridge of the pedicle valve is well thickened but anteriorly the ridge is seldom well developed. The sulcus of the exterior accounts for a strong interior fold. The adductor scars are shown well in many of the pedicle valves and appear on each side of the median septum at its base. The marginal rim is developed in varying degree but is always present, forming the flattened area on each side of the visceral region. The flattened part is finely granulose but the inner slope adjacent to the inner edge of the border is coarsely granulose. Inside the brachial valve the thickened margin of the visceral area forms a reniform elevation starting between the adductor scars and extending laterally, then swinging parallel to the margin to form a sharp loop at the anterolateral extremity and bounding the deep median trough.

Between the adductors the anderidium is well

developed in some specimens, not so well in others. The brevisseptum is elevated into a high crest at the posterior head of the median trough and is commonly spinose.

This genus is best developed in the Cisco Group of Texas, where it is abundant in places. It extends into the Neal Ranch Formation of the Wolfcampian but it is rare there.

*Sulcataria? compacta*, new species

PLATE 480: FIGURES 56-62

Small, compact, transversely rectangular in outline with variable hinge, slightly narrower or wider than midwidth. Sides varying from slightly rounded to slightly oblique. Cardinal extremities acute to nearly right angle. Anterior margin broadly rounded and medially indented. Anterior commissure with narrow dorsad fold. Posterior margin with 5 oblique spines.

Pedicle valve strongly and somewhat narrowly convex in lateral profile; anterior profile broadly domed and with long, steeply sloping sides and indented crest. Umbonal region narrowly swollen; median region strongly inflated and divided by strong, narrow and deep sulcus originating on umbo and indenting anterior margin. Flanks forming two narrow plications; anterior slope steep. Interarea long, orthocline to anacline.

Brachial valve moderately concave, concavity forming broadly triangular area deepest at umbo. Fold strong and narrowly rounded, originating near midvalve and separating two troughlike shallow areas. Posterolateral extremities flattened and well demarcated by oblique folds forming dorsad wave in lateral margin.

Pedicle valve interior with thick apical callosity and short thick median septum. Ridge anterior to septum not conspicuous and variable, usually low and not reaching midvalve. Teeth short and wide.

Brachial valve interior with cardinal process thickened, and antron filled in adults; prosocket ridges thick and bounding deep sockets. Adductor dividing ridges strongly thickened and extended in anterior direction. Anderidia slender but prominent. Visceral region divided by deep median trough from midvalve to anterior margin. Brevisseptum low and thick, located at posterior end of median trough and extending as low ridge nearly to car-

dinal process. Visceral region greatly thickened anteriorly and laterally.

MEASUREMENTS (in mm).—Thickness of holotype 2.4; of others, unmeasurable.

	<i>brach- ial valve length</i>	<i>sur- face length</i>	<i>hinge width</i>	<i>mid- width</i>	<i>height</i>	
USNM 701						
152080a (holotype)	6.6	5.4	8.5	9.8*	9.2	3.3
152080b	5.8	?	8.5	9.8*	9.2	3.3
152080c	5.8	?	7.0	9.2	8.9	2.6
152080d	?	6.3	?	9.0?	9.6	?

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (lower 15 feet of bed 2).

LOCALITY.—USNM 701.

DIAGNOSIS.—Transversely rectangular, thick-shelled *Sulcataria* with fairly narrow sulcus.

TYPES.—Holotype: USNM 152080a. Figured paratype: USNM 152080d. Measured paratypes: USNM 152080b-d. Unfigured paratypes: USNM 152080b, c, e.

DISCUSSION.—Like most of the other Chonetacea from the Wolfcampian, this is a rare and difficult species to find. It is distinguished by its small size and in this respect is unlike other known *Sulcataria*. The wide hinge may be a youthful character but the largest specimens of the 15 known are wide-hinged. The sulcus is not rapidly expanding as usual in this genus but it is bordered by fairly strong plications. The best preserved shells are definitely smooth but the abraded ones show a crude striation.

*Sulcataria latisulcata*, new species

PLATE 478: FIGURES 57-68; PLATE 480: FIGURES 32-35

Outline roundly and transversely rectangular, hinge narrower than midwidth. Cardinal extremities forming obtuse angle; sides moderately rounded; anterior margin broadly rounded to subtruncate or slightly emarginate. Anterolateral extremities broadly rounded. Anterior commissure with broad but subcarinate dorsal fold. Posterior margin with oblique spines of uncertain number (more than five on a side).

Pedicle valve fairly evenly but very gently convex in lateral profile; anterior profile forming broad curve, slightly indented medially, sides long and



gently sloping. Umbonal region narrowly but gently swollen. Median region slightly inflated. Sulcus originating just anterior to umbo, narrow and shallow at origin but broadening and deepening anteriorly to occupy about half width of front margin. Flanks bounding sulcus broadly rounded in anterior half; posterolateral slopes long and gentle; posterolateral extremities flattened and slightly deflected ventrally. Interarea short, apsacline.

Brachial valve fairly deeply concave in postero-median and umbonal regions but deflected dorsally in anterior half. Posterolateral extremities flattened; anterolateral extremities gently concave and forming shallow oblique troughs. Fold originating near midvalve, variable, ranging from broadly to somewhat narrowly subcarinate.

Pedicle valve interior with small teeth and small, short median septum not continued anteriorly as median ridge. Lateral and anterolateral margins broadly flattened.

Brachial valve with a broad, excavated cardinal process and wide, slender prosocket ridges. Adductor dividing ridges not strongly developed. Anderidium poorly discernible. Median region deeply sulcate; brevisseptum low, not extending to antron. Antero-median extremities of visceral area thickened and somewhat spinose.

MEASUREMENTS (in mm).—From locality USNM 701 specimen 152082a (holotype) and from 701d specimen 152084a, respectively: length 8.9, 8.6; brachial valve width 7.8, (?); surface length 10.5, 10.0; hinge width 13.0, 12.6; midwidth 14.6, 13.8; height 2.7, 2.5; thickness 1.9, (?).

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation.

LOCALITIES.—USNM 701, 701d.

DIAGNOSIS.—Medium-sized, transverse *Sulcataria* with rounded sides and broad anterior sulcus.

TYPES.—Holotype: USNM 152082a. Figured paratypes: USNM 152082b, 152084a. Measured paratypes: USNM 152084a. Unfigured paratype: USNM 152084b.

COMPARISONS.—This species is about the same size as *Sulcataria rostrata* (Dunbar and Condra) but has a lesser development of the fold which, although originating at the beak, is only slightly impressed posteriorly. The sulcus widens rapidly anteriorly but is not deeply impressed. The fold on the brachial valve is broad and gentle, unlike that

of *S. rostrata*, which is narrow and subcarinate. Internally the valves are much less thickened than those of the Cisco species. No trace of radial marks is to be seen on these Wolfcampian specimens.

DISCUSSION.—This is an extremely rare species; only five specimens are known from the tons of Wolfcampian limestone processed. The species is interesting because of the soft outlines of the exterior, the lack of radial ornament and the delicate interior details.

### *Sulcataria rostrata* (Dunbar and Condra)

PLATE 480: FIGURES 37–55

*Chonetina?* *rostrata* Dunbar and Condra, 1932:150, pl. 19: figs. 1–3, 5–7.—Cooper and Grant 1970: 579.

Illustrations of *S. rostrata* (Dunbar and Condra), type-species of *Sulcataria*, are introduced for comparison with the Glass Mountains species from the Gaptank and Wolfcampian rocks. The lectotype, shown on Figure 1 of Plate 19, comes from the Cisco Group, Graham Formation (shale above the Jacksboro Limestone) on the Brazos River, south-east of Graham, Texas, not as cited by Cooper and Grant (1969:5).

STRATIGRAPHIC OCCURRENCE AND LOCALITY.—As above and from the Graham Formation (Wayland Member), USNM 510a, and Graham Formation (Gunsight Member), USNM 518v.

TYPES.—Lectotype: YPM S2164 = Dunbar and Condra (1932, pl. 19: fig. 1; not YPM S2166a as cited by Cooper and Grant, 1969:5). Figured paratypes: YPM S2164b–f. Figured hypotypes: USNM 153684a–i.

### *Sulcataria* species

Two other species of this genus are represented in the Glass Mountains.

SPECIES 1.—A specimen (USNM 155050) from the *Uddenites*-bearing Shale Member (USNM 701p) is similar to *S. rostrata* (Dunbar and Condra). It is smaller than that species, with well-rounded sides and a narrower hinge. Its sulcus is wider at the beak and is much deeper at the front margin, when compared with specimens of the same size of *S. rostrata*, suggesting that the Glass Mountains specimen is an adult. The deep sulcus has a correspondingly high fold which strongly indents the anterior mar-



gin. Where exfoliated, the surface is faintly radiate. Measurement (in mm): length 7.4, brachial valve length 5.6, surface length (at middle) 9.5, hinge width 8.4, midwidth 11.9, height 2.6, thickness 2.1.

SPECIES 2.—A specimen (USNM 155051) from the Lenox Hills Formation (USNM 716r) is unlike any of the others. The folding is like that of *Sulcataria*, with the sulcus beginning at the beak and widening rapidly to the margin, which is deeply indented, but the specimen is very slender and with very little height. The fold is fairly long and subcarinate, but the sides are indented near midvalve, indicating a fairly wide hinge. The shallowness of the pedicle valve and the wide hinge distinguish this species from any other. Measurements (in mm): length 8.9, brachial valve length 8.3, surface length 9.5, hinge width 13.8\*, midwidth 12.4, height 1.3, thickness 0.3.

### Genus *Neochonetes* Muir-Wood, 1962

*Neochonetes* Muir-Wood, 1962:87.—Williams et al., 1965: H431.

*Quadranetes* Sadlick, 1963:721.

Fairly large, generally rectangular to subtrapezoidal; cardinal extremities usually auriculate; valves moderately to strongly concavo-convex. Surface covered by fine, closely crowded costellae. Spines along posterior margin short, oblique. Anterior commissure not folded.

Pedicle valve with short pseudodeltidium forming elevated rim on delthyrial margins; interarea moderately long. Teeth wide; median septum short; ridge anterior to median septum low, inconspicuous, not reaching midvalve and flanked by low ridge on each side. Adductor field oval, located at anterior end of median septum. Diductor scars oblique, triangular, not surrounding adductor field anteriorly. Lateral slopes granulose.

Brachial valve with large tetralobate cardinal process, dorsal half covered by convex chilidium. Prosocket ridge moderately strong, fairly wide. Adductor dividing ridges long and slender with well developed anderidium. Brevisseptum low but most elevated anteriorly, passing into short rows of blunt spines; extended posteriorly, joining callus thickening anterior to antron. Anterior and lateral margins of visceral area slightly thickened and moderately granulose to spinose.

TYPE-SPECIES.—*Chonetes dominus* R. H. King (1938: 259, pl. 36: figs. 1–7).

DIAGNOSIS.—Finely costellate Chonetacea with a slightly developed median ridge in the pedicle valve, slight thickening of the visceral region in the brachial valve, and no regularly developed fold and sulcus.

COMPARISONS.—This genus can be recognized by its generally large size and widely extended hinge in which respect it resembles *Dyoros* Stehli but is readily distinguished by the numerous fine costellae. *Neochonetes* is costellate but not so strongly costellate as *Chonetinella* Ramsbottom but it is readily distinguished from that genus by the lack of the narrow and deep sulcus. *Megachonetes* Sokolskaya of the Carboniferous of Europe and Russia is also finely costellate but this is a large, broadly expanding and flattish shell. *Plicochonetes* Paeckelmann is usually much smaller than *Neochonetes*, is more strongly costellate or costate, and has no median septum, features that readily distinguish the two genera.

*Neochonetes* does not have the wrinkled effect on the costellae so characteristic of the Russian Carboniferous genus *Rugosochonetes* Sokolskaya. *Neochonetes* is now the only large costellate chonetoid known from the Upper Paleozoic in North America.

DISCUSSION.—When *Chonetes variolata* as interpreted by de Koninck was regarded as the type species of *Chonetes*, these costellate Upper Paleozoic shells were appropriately placed under *Chonetes*. Now, however, following the leads of Ramsbottom (1952) and Imbrie (1959:394) who determined the type species to be a Devonian form with totally different structure, the name *Chonetes* is no longer appropriate for them. *Neochonetes* includes the common *Chonetes granulifer* (Owen) and the subspecies *C. g. transversalis* Dunbar and Condra. These authors reduced Girty's *C. meekanus* to varietal rank but it appears to be a distinct species. *Chonetes brazosensis*, *C. granulifer emaciatus* and *C. puebloensis* all proposed by R. H. King are referable to *Neochonetes*.

Excellent specimens showing all details of the interior make it possible to add information on parts of the chonetid shell not usually so well preserved in other genera. The teeth are fairly large and slightly oblique to the hinge margin and are moderately thickened along their under surface

where a small fossette aids in the articulation behind the prosocket ridges. The apical callosity is not strongly developed but the short septum just anterior to it is well formed but very short. It extends anteriorly from the callosity only to the posterior extremity of the adductor field. In some specimens the median line of the pedicle valve anterior to the adductor field is bounded on each side by a narrow band of coarse granules.

The adductor scars, well displayed in many specimens of this genus, consist of four scars, two suboval anterior ones and two posterior ones usually smaller and elongated, occupying the posterior and outer side of the anterior pair. In one specimen the anterior adductors have a dendritic pattern reminiscent of the Productacea.

The diductor scars are somewhat triangular and anteriorly partly surround the adductor scars. A submarginal but only slightly flattened rim of fine granules surrounds the concave visceral region. Most of the inner surface is finely to coarsely granulose.

The cardinal process is similar to that of all the Upper Paleozoic chonetids but is flattened and has a small antron under it. The prosocket ridges are narrow, moderately deep slitlike sockets. Over these an extension of the palintrope hangs in the form of small, thin plates which overlap the teeth and help in the articulation. The adductor dividing ridges are slender and long and usually the anteridium is elevated anterior to the middle of the ridge. It appears as an elongated, slender blade, slightly flattened and of different shell structure than that of the tissue surrounding it. The brevisseptum originates anterior to the antron and is low, but elevates slightly anteriorly to form a low angular crest at the distal end. This extremity is generally expanded and its anterior slope is strongly and coarsely spinose.

The visceral region is defined by a convex band of granules extending from near the distal end of the prosocket ridges in a convex loop to terminate near the anterior end of the brevisseptum. In most specimens this band of granules is fine but in others the granules are coarse; in no case is the band conspicuously elevated and thickened as it is in *Dyoros*.

This genus in the Permian of the Glass Mountains is confined to Wolfcampian rocks. Two species are represented by a fair amount of material but other poorly preserved or sparsely represented

species are not described. Exfoliated specimens were taken from the Lenox Hills Formation but could not be identified specifically. The genus is well represented and abundant in the shaly Wolfcampian of north-central Texas in the Camp Colorado, Moran, and Harpersville formations. It is also common in the Florena Shale of Kansas and in the Stine and Hughes Creek shales of Nebraska.

### *Neochonetes dominus* (R. H. King)

PLATE 497: FIGURES 1-18

*Chonetes dominus* R. H. King, 1938:259, pl. 36: figs. 1-7.

Illustrations of the type species, *N. dominus* (R. H. King) are introduced to show the generic characters in detail. The specimens are from the Pennsylvanian Bend Formation (Marble Falls Member), on Texas highway 81, 2.7 miles south of San Saba, San Saba County, Texas.

Types.—Figured hypotypes: USNM 153738a-g.

### *Neochonetes liratus*, new species

PLATE 496: FIGURES 26-52

Medium size for genus, rectangular, width greater than length, hinge usually slightly less or slightly greater than midwidth. Posterolateral extremities forming slight ears; sides generally nearly straight or slightly rounded and indented slightly just anterior to ears. Anterior margin broadly rounded to subtruncate. Anterior commissure not folded. Surface finely costellate, closely crowded, threadlike, numbering 5 or 6 per mm at front margin of large specimen.

Pedicle valve gently but somewhat unevenly convex in lateral profile, greater convexity in posterior half, anterior slightly flattened. Anterior profile low dome gently convex to flattened on crest and with long moderately sloping sides. Umbonal and median regions moderately swollen; umbonal slopes long and gentle; lateral slopes gentle but anterior slopes the steepest. Sulcus indistinct or not formed. Interarea short, orthocline to anacline. Pseudodeltidium rimlike.

Brachial valve gently concave, deepest part in posteromedian region and flattening anteriorly.

Flanks flattened to slightly concave. Posterolateral extremities flattened and slightly deflected toward pedicle valve. Interarea short, hypercline; chlidium strongly developed and covering posterior half of cardinal process.

Pedicle valve interior with teeth short, wide, having slitlike fossettes; apical callosity small; median septum short, thin, strongly elevated. Ridge ante-

rior to septum not reaching midvalve and flanked by low ridge on each side. Surface granulose.

Brachial valve interior with large, deeply excavated cardinal process and long prosocket ridges; adductor dividing ridges long but anderidium not well developed. Brevisseptum low, terminating in callus wash just anterior to antron. Visceral region granulose but not thickened.

MEASUREMENTS (in mm).—							
	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 701	10.1	8.6	13.0	14.6	13.7	3.7	2.7
152104a	13.2	10.6	15.5	19.4	18.4	4.5	2.9
(holotype)							
152104b	12.5	11.0	15.0	18.9	18.1	3.8	2.6
152104c	11.6	10.2	14.0	16.0	16.4	3.8	2.6
152104d	10.3	9.0	12.0	15.3	14.9	3.1	2.1
152104e	9.7	8.7	11.5	16.4	15.0	3.3	2.1
152104f	9.8	8.7	11.0	15.0	14.4	2.8	2.0
152104g	10.0	7.7	12.0	15.7	14.3	3.8	?
152104h	8.7	7.8	9.5	13.6	12.7	2.3	1.7
152104i	8.0	7.0	9.5	12.8	12.2	2.6	1.7
152104j	7.7	7.0	9.0	11.2	11.9	2.4	1.5
152104k	6.3	5.9	7.0	10.5	10.0	2.0	1.4
152104l	5.7	5.1	6.0	9.6	8.8	1.7	1.3

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member), Neal Ranch Formation.

LOCALITIES.—*Uddenites*: USNM 701e, 701p, 701q, 701t, 701v, 702j. Neal Ranch: 701, 701a<sup>3</sup>, 701c, 701d, 701h, 727e.

DIAGNOSIS.—*Neochonetes* of moderate size with hinge only moderately extended and interior finely granulose.

TYPES.—Holotype: USNM 152104a. Figured paratypes: USNM 152103; 152104d, e, h; 153735 a–c. Measured paratypes: USNM 152104b–l. Unfigured paratypes: USNM 152104b, c, f, g, i–l.

COMPARISONS.—This species is unlike any of those described from north-central Texas, Kansas, or Nebraska in having the hinge only slightly extended laterally and in having the interior finely granulose. It suggests *N. dominus* (R. H. King) in having only slightly extended cardinal extremities but its interior is not so strongly thickened as the Marble Falls species. This is a larger species than *N. parvus*, new

species, and has a less concave brachial valve and different exterior form.

DISCUSSION.—This species is represented by numerous specimens including many young ones. Considerable variability is indicated in the young, especially along the hinge. In some specimens this is definitely wider than midwidth but in others it is nearly equal. The cardinal extremities vary from angular to rounded obtuse and a few specimens have small ears.

Interior details are characteristic of the genus. The pedicle valve has a short septum but no median ridge. The interior of the brachial valve is characterized by its delicacy but the adductor dividing ridges are well thickened and prominent.

*Neochonetes parvus*, new species

PLATE 496: FIGURES 53–65

Small for genus, semicircular, hinge widest, measuring not quite twice length. Cardinal extremities

forming acute ears having angle of about  $70^\circ$ . Sides oblique and slightly indented anterior to ear. Anterior margin broadly rounded. Anterior commissure unfolded. Surface finely costellate, costellae numbering 5 per mm at front margin. Posterior margin marked by 8 moderately long oblique spines.

Pedicle valve with fairly even and moderately convex profile; anterior profile forming broad gentle dome with long gently sloping sides. Umbonal region narrowly swollen; median region broadly and moderately inflated. No sulcus. Anterior slopes steeper than lateral ones. Cardinal extremities depressed. Interarea short, orthocline to anacline.

Brachial valve broadly and moderately concave medially, sides and anterior sloping gently toward middle. Posterolateral extremities flattened and demarcated by low oblique ridge. Intrarea short and hypercline.

Pedicle valve interior with small, wide, flat teeth and small apical callosity; median septum short but strongly elevated and not continued anteriorly as median ridge.

Brachial valve interior with wide, excavated cardinal process and wide, stout, thick prosocket ridges. Adductor dividing ridges long and slender, with protruding anderidium. Brevisseptum low, stout, anteriorly spinose, and not extending to antron. Anterior slopes marked by rows of stout erect spines.

MEASUREMENTS (in mm).—From locality USNM 701c, specimen 152115a (holotype): length 9.4, brachial valve length 8.2, surface length 11.0, hinge width 17.2, midwidth 14.0, height 3.4, thickness 2.1.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (beds 4–14 of P. B. King).

LOCALITIES.—USNM 701c, 701d, 701k, 721g.

DIAGNOSIS.—Small, moderately concave *Neochonetes* with well-formed ears.

TYPES.—Holotype: USNM 152115a. Figured paratypes: USNM 152115b, 153737.

COMPARISONS.—This species is best compared with *N. liratus*, new species, from which it differs in its smaller size, more pronounced ears, and the greater concavity of the brachial valve. It differs from *N. dominus* (R. H. King) in its well-defined ears, different shape, and more concave brachial valve.

DISCUSSION.—This species is represented by a few specimens only, most of them young. Interiors are few; the pedicle valves have a slender and short

septum and the brachial valves are delicately constructed but have a prominent anderidium.

### *Neochonetes meekanus* (Girty)

PLATE 497: FIGURES 27–30

*Chonetes meekanus* Girty, 1915:60.

Illustrations are introduced for comparison with other species of *Neochonetes*.

STRATIGRAPHIC OCCURRENCE AND LOCALITY.—Hughes Creek Formation, U. S. highway 75, 5 miles south of Dawson, Nebraska.

TYPES.—Figured hypotypes: USNM 152119a–c.

### *Neochonetes puebloensis* (R. H. King)

PLATE 497: FIGURES 19–26

*Chonetes puebloensis* R. H. King, 1938:262, pl. 37: figs 1–6.

Illustrations of *N. puebloensis*, a species fairly common in the Permian of north central Texas are introduced for comparison with other Wolfcampian species.

STRATIGRAPHIC OCCURRENCE AND LOCALITY.—Pueblo Formation, one mile south of Camp Colorado, Coleman County, Texas; USNM 766.

TYPES.—Figured hypotypes: USNM 152124; 153739a, b.

### *Neochonetes* species indeterminate

Localities from which unidentifiable specimens were taken are: Gaptank Formation (*Uddenites*-bearing Shale Member): USNM 701e, 701p, 701t. Neal Ranch: USNM 701d, 701k, 715b. Lenox Hills: USNM 707j, 715.

### Genus *Dyoros* (*Dyoros*) Stehli, 1954

*Dyoros* Stehli, 1954:312—Muir-Wood 1962:87.—Williams et al., 1965:H430.

Large, chonetiform shells having acute to alate cardinal extremities. Widest along hinge. Anterior commissure broadly to narrowly uniplicate. Valves concavo-convex, brachial valve usually not deeply concave. Surface smooth except for concentric lines and varices of growth.

Pedicle valve interior with strongly developed but short pseudodeltidium; interarea moderately long. Teeth strong; median septum well defined posteriorly but extending anteriorly to beyond midvalve in some species. Diductor scars subflabellate. Submarginal rim not strongly developed, defined by coarse taleolae.

Brachial valve interior with strong chilidium; cardinal process deeply excavated anteriorly, but quadrilobed on posterior face. Outer socket ridges weakly to moderately strongly developed. Prosocket ridges weakly developed. Anderidia variously developed. Median septum strongest at midvalve, lessening posteriorly or replaced by callus but rising anteriorly, extremity marked by several short "spines" or taleolae. Adductor scars lightly impressed. Inner taleolae strong and prominent in one or more curved rows at edge of anterolateral slope.

TYPE-SPECIES.—*Chonetes consanguineus* Girty (1929:409, figs. 8, 9).

DIAGNOSIS.—Wide-hinged smooth Chonetacea with sulcus varying from deep to barely visible, the pedicle valve and visceral region usually strongly fringed by spines on the anterolateral side.

Subgenus *Dyoros* with strong angular ears and deep sulcus; new subgenus *Lissosia* having a wide hinge and strong ears but a reduced sulcus; new subgenus *Tetragonetes* having reduced ears, nearly vertical sides, and strong sulcus.

COMPARISONS.—Stehli (1954) considered the most important feature of *Dyoros* to be the fringe of "enlarged papillae" around the visceral disc (anterior and lateral). Other features of importance are the proportionately great width, distinct ears, the strong median sulcus, and the smooth exterior. The genus thus does not need to be compared with any of the striate chonetids. It should be mentioned, however, that sporadic occurrence of radii appears in two species of the genus.

The genus *Dyoros* differs from *Lissochonetes* Dunbar and Condra in the interior details of both valves. It usually has fairly strong ridges in the pedicle valve, whereas *Lissochonetes* does not; and it has on the anterior and sides of the visceral region a strong fringe of spines, which *Lissochonetes* also does not have. *Dyoros* (*Dyoros*) is usually more convex and is always more deeply sulcate than the other genus. Some species of *D. (Dyoros)* approach *Lissochonetes* in having a slightly fringed visceral

region. Other species with this region more like *D. (Dyoros)* may have very reduced ridges in the visceral region of the pedicle valve.

*Tornquistia* Paeckelmann is a smooth genus but it is small, with different proportions and is not provided with a median sulcus. Furthermore the brachial valve interior has two diverging septa in midvalve, totally unlike *Dyoros* (*Dyoros*). *Chonetina* Krotov is small, deeply sulcate, internally septate in the brachial valve and with a habit totally unlike *Dyoros* (*Dyoros*). The same may be said of *Quadrochonetes* Stehli which is small but with a very wide sulcus bordered by two subangular plications.

*Leurosina*, new genus, differs from *D. (Dyoros)* in having no sulcus or merely a broad deflection of the anterior margin and decidedly rectangular outline with angles rounded.

DISCUSSION.—The members of this genus, except for some species of *D. (Tetragonetes)*, are generally large and strongly transverse, but some variation exists in these features. The genus is generally well distributed in the Middle and Upper Permian in southwestern United States but has not yet been identified outside of this region. It is usually easy to identify by the above characters and the smooth exterior of both valves.

The distinctive transverse form of *D. (Dyoros)* is produced by the wide hinge and the prominent ears, which in some species are so drawn out as to be almost mucronate. Generally, however, the ears vary between 30° and 60°, although some individuals are outside these limits. The height of the valves is variable, ranging from strongly convex to flatly convex. A fairly strong to deep sulcus is also a mark of *D. (Dyoros)* but variation in this feature occurs on the specific and individual levels. The sulcus varies from broad in *D. (D.) extensus*, new species, to narrow and almost slitlike in *D. (D.) consanguineus* (Girty). The stronger the sulcus the greater the effect it has on the anterior margin. In species having a deep and strong sulcus, the anterior margin is usually fairly strongly indented, imparting a lobate form to the anterior.

The ears on the pedicle valve are usually strongly to moderately convex. In the strongly convex species having a deep sulcus, the ears are commonly depressed and may be marked by a prominent oblique sulcus that indents the lateral margin to some degree. This feature is variable within the



species but is generally well exhibited by *D. (D.) extensus* and *D. (D.) convexus*, new species.

The posterior margin of *D. (Dyoros)* is well provided with hollow spines increasing in length laterally. Generally the spines are short and are arranged obliquely along the margin, with their extremities directed laterally. The pseudodeltidium is well-formed, moderately convex but short. This structure appears as a fold of the outer layer of the palintrope and overlies the edge of the tooth that forms the delthyrial margin. In many specimens the anterolateral edge of the pseudodeltidium curls away from the edge of the tooth, indicating clearly its relationship to the outer layer of the palintrope. Buttressing of the pseudodeltidium is evidently by growth of apical callosity rather than by a callus smear on the sloping wall of the tooth and under side of the pseudodeltidium. Throughout the genus the interarea is generally flat or slightly curved and usually maintains an orthocline or apsacline position; it is not long and little variation has been detected among the species.

The brachial valve varies from gently to strongly concave and the greatest concavity is generally near midvalve. The umbonal region is always a deep pit. The fold, which is variable, generally originates near midvalve and is usually strongest in the anterior third. The fold usually affects the interior and accounts for the commonly deep median trough anterior to the brevisseptum. The chilidium is a thin and delicate but prominent plate that covers the dorsal part of the cardinal process. The interarea is generally shorter than that of the opposite valve and is flat, in a hypercline position.

The teeth on the inside of the pedicle valve are usually strong and prominent, forming a broad, oblique plate under the palintrope edge and bordering the delthyrial cavity. The dorsal surface extends beyond the palintrope edge and is smooth and flat. The inner face forming the delthyrial edge is notched toward the valve floor to form a fossette against which the "socket plate" rests.

The delthyrial cavity is occupied by a callosity at the apex. This accumulation of shell material helps to weight the posterior and to support and protect the pseudodeltidium. Anterior to the callosity a short but commonly elevated septum is extended to the posterior part of the adductor field. This short septum, variable in width and length, in some specimens extends barely to the posterior edge of the

adductor field but in others it passes for a short distance between the adductor scars. In some it is slender but in others it is wide and flattened on its dorsal face. The flattened face is an accommodation to the movement of the ventral face of the cardinal process. In many species a thin, low ridge extends anteriorly from the short septum described above. In *D. (Dyoros) consanguineus* this ridge is poorly developed but in *D. (Dyoros) extensus* it is well formed and fairly prominent, extending anteriorly to well beyond midvalve. In this and some other species the height of this ridge is further emphasized by the fact that it is located on the inner median convex fold representing the sulcus of the exterior. This low ridge is, perhaps, best called a myophragm because it bisects the large flabellate diductor field. In some specimens the anterior, or distal, end of this myophragm is provided with a few spinelike taleolae.

A few specimens exhibit the muscle field in detail. The adductor scars are four in number, arranged in pairs and forming an elliptical patch located at the base of the short elevated median septum at the apex of the muscle field. The posterior pair of adductor scars is smaller than the anterior pair, are triangular in outline and located at the base of the short septum. The anterior pair is larger, also triangular, and lies on the sloping sides of the low ridge extending anterior to the short septum. In *D. (Dyoros) consanguineus* the larger rests directly on the valve floor. In old specimens of *D. (Dyoros) extensus* the posterior scars are partly attached on the sides of the short septum and callus is deposited around the posterior end.

The diductor scars are triangular and broadly flabellate. They surround the adductor field anteriorly. The anterior broad part of the diductor scars is marked by low, elevated ridges. In some specimens of *D. (Dyoros) extensus* (from USNM 707e) the diductor scars are marked by strong longitudinal ridges and by rows of strongly elevated spines as well. This feature, also seen in *D. (Dyoros) transversus*, which occurs at the same locality, may be ecological in origin.

The inside of the pedicle valve is marked by rows of papillae, probably taleolae, strongest in the lateral areas and ears. A narrow band of small papillae forms a border around the inside margin. This corresponds to a similar band inside the opposite valve.

Large and old specimens of *Dyoros* (*Dyoros*) exhibit to perfection interior details of the brachial valve. The cardinal process is generally fairly large and complicated. It is usually deeply excavated anteriorly by an antron, although in older specimens this may be partially or nearly completely filled by adventitious shell. The cardinal process when viewed from the dorsal side is definitely bilobed, but the two lobes have been tightly squeezed laterally and pressed together. The posterior face of the cardinal process is marked by four ridges, the larger two closely appressed and located on each side of the slit dividing the structure into two lobes. The two smaller ridges appear on the outside of the cardinal process and the whole is overlaid on the postero-dorsal side by the convex chilidium. The four ridges thus form two narrow triangles with long sides adjacent and their intermediate angle forming the outside angle. It is probable that the four ridges are the sites of diductor muscle insertions.

The sockets are deep and slitlike, with a flat, slightly sloping floor. On the outside of the socket and underlying the palintrope surface is a small plate that slightly overhangs the socket, the outer socket plate of Imbrie (1959:394). This is essentially an accessory tooth that interlocks with the outer sloping edge of the tooth of the pedicle valve. The main part of the tooth rests on the broad sloping surface of the socket, that is, the surface of the socket plate. The edge of the socket plate locks with the ridge on the tooth which forms the boundary of the fossette. These ridges and accessory tooth make for a rigid but simple articulation.

Brachial bases (Imbrie, 1959:394 = brachio-phores) were not observed in brachial valves of this genus. The plates may be there, but buried under heavy deposits of adventitious shell. They were not observed in the smallest specimens available and may have become obsolete by Permian time. Pro-socket ridges, however, are well developed and prominent, forming the anterior side of the socket. These structures are variably developed within the species and between species. They form the outside pair of five prominent ridges that radiate from the vicinity of the cardinal process.

The antron of the young specimens is deep but in old individuals it becomes partially filled and the area immediately anterior to it is considerably thickened. In addition to this thickening a number of ridges help to strengthen the midvalve region.

The median septum of the brachial valve is similar to the brevisseptum of the Productidina in its location at midvalve and the fact that it does not extend to the cardinal process but dies out before reaching the notothyrial platform. In some old specimens the median septum is extended posteriorly to, or nearly to, the cardinal process by deposition of excess shell. The stouter anterior part of the brevisseptum thus is extended posteriorly and simulates a strong septum, low in the posterior direction. Anteriorly the septum is elevated to a crest at its distal extremity, which slopes off abruptly into the trough between the lateral elements of the visceral region. At its anterior end and on the sloping anterior face the median septum commonly bears several to many blunt spines or taleolae. In *D. (Dyoros) transversus*, new species, these spines are festooned over the anterior end of the septum and along the sides of the median trough to join the fringe of spines along the anterolateral border of the visceral region.

A short septum, or ridge, appears on both sides of the median septum. Each ridge consists of two parts; the first, or posterior, part is a rodlike, oblique plate buried in the posterior end of the ridge, but the distal end projects as a short, free point. This small plate, the anderidium of Sadlick (1965), suggests the brachiophore of the Plectambonitacea. The shell substance of this rod is clearly different from that of the remainder of the ridge. The second, or anterior, part of the ridge, underlying the free distal point, is clearly adventitious shell laid down in continuation of the posterior portion of the ridge surrounding the rodlike plate. These are the adductor dividing ridges of Imbrie (1959:394). These small rodlike anderidia appear in many chonetid genera and may have supported the body wall with the mouth midway between. They would thus serve as crural processes.

The adductor scars consist of two pairs: an inner anterior pair and an outer posterior pair separated by the ridges referred to above. These scars are usually not distinct in any of the members of this genus.

The visceral region of *Dyoros* (*Dyoros*) is not prominently marked until late in life when the anterolateral region is thickened and becomes strongly spinose. The visceral region consists of two elevated loops or crescents with the posterior point near the distal end of the brachial bases and the anterior hook located on each side of the median

trough formed by the exterior fold. In old shells, one or more rows of prominent taleolae or spines project anteroventrally in a fringe especially prominent at the anterolateral extremity. In *D. (D.) transversus* the spines occur on each side of the median trough and anterior of the median septum as well in their usual anterolateral position. The region bounded by these spiny crescents or hooks is usually strongly papillose. A band around the margin is finely papillose and corresponds to the narrow band inside the margin of the pedicle valve.

*Dyoros (Dyoros) angulatus*, new species

PLATE 481: FIGURES 11-44

Small for genus, subtrapezoidal in outline, hinge widest, about twice length. Cardinal extremities mucronate. Sides nearly straight, strongly sloping medially to gently concave. Anterior margin indented; anterolateral extremities narrowly rounded. Anterior commissure with strong, subangular dorsad wave. Posterior margin with seven oblique spines.

Pedicle valve fairly evenly and moderately convex in lateral profile and most convex near midvalve. Anterior profile a moderately rounded dome with

long, moderately steep, sloping sides; crest deeply indented. Umbonal region moderately swollen. Median region strongly inflated but with moderately steep slopes. Sulcus variable, originating just anterior to umbonal region, narrow and deepening anteriorly, strongly indenting anterior margin. Flanks forming narrowly rounded plications on each side of sulcus. Interarea short, orthocline to anacline.

Brachial valve deeply concave, most concave medially; sides sloping moderately; anterior sloping gently toward midvalve. Fold originating just anterior to umbonal region, variable, usually narrowly rounded to subangular; ears well demarcated, moderately concave. Interarea short, hypercline.

Pedicle valve interior with small teeth, thick apical callosity and short but strongly elevated median septum. Ridge anterior to median septum not well developed. Interior granulose.

Brachial valve interior with medium-sized, excavated cardinal process and moderately long prosocket ridges. Adductor dividing ridges long and with well developed anderidium. Brevisseptum reduced and low, anterior serrate. Visceral area anterolaterally thickened and coarsely spinose.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 707e							
151969a	9.0	8.0	11.5	19.0	13.0	3.8	2.1
151969b	7.8	6.9	10.0	17.5	11.8	3.2	2.0
151969c	7.4	6.5	9.5	14.4	10.5	3.0	2.1
151969d	6.4	5.6	8.0	14.2*	10.2	2.8	1.6
151969e	6.6	5.6	8.5	12.6	9.2	2.9	1.9
151969f	6.4	5.5	8.9	12.3	9.8	2.6	1.7
151969g	6.4	5.5	7.5	12.0	9.1	2.8	1.9
151969h	5.7	4.9	7.5	11.5	8.5	2.7	1.7
151969i	5.0	4.4	6.5	10.7	7.8	2.3	1.3
151969j	4.4	3.8	5.5	8.0	6.6	1.9	1.1
USNM 710z							
153685a	6.0	5.6	7.0	11.5	7.9	3.0	1.5
(holotype)							

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—AMNH 503, 509; USNM 703, 703c, 703d, 707e, 710z, 720d, 721j, 722g, 723x, 724a, 726d, 726e.

TYPES.—Holotype: USNM 153685a. Figured paratypes: USNM 151969a,b; 153685b; 153686a, b;

153687b; 153688. Measured paratypes: USNM 151969a-j. Unfigured paratypes: USNM 151969c-j; 153687a.

DIAGNOSIS.—Small, alate *Dyoros (Dyoros)* with the sulcus narrow and strongest on the anterior slope; brachial valve with narrow, carinate fold.

COMPARISONS.—As usual in the subgenus, *D.*

(*D.*) *angulatus* has a wide hinge and the cardinal extremities are drawn into slender points. Development of the fold suggests *D. (D.) consanguineus* (Girty) but the new species is smaller, more laterally extended and the fold of the brachial valve is less well developed.

*Dyoros (Lissosia) parvus*, new species, occurs at the same locality as *D. (D.) angulatus* but is readily distinguished from it by its much less convex pedicle valve, much less well developed sulcus on the pedicle valve and almost complete lack of a fold on the opposite valve. Although *D. (L.) parvus* is fairly strongly developed laterally it is not usually as greatly extended as *D. (D.) angulatus*.

*Dyoros (D.) tenuis*, new species, is not likely to be confused with *D. (D.) angulatus*, although it is similar in size. It is less extended laterally, is not so convex, and the sulcus is broad and shallow in contrast to the narrow and deep sulcus of *D. (D.) angulatus*.

DISCUSSION.—The interior details of this species do not depart from the normal for the genus. The anterolateral extremities of the visceral disc are strongly granulose to spiny and the median septum is normally developed and serrate anteriorly. None of the bizarre spinescence of such species as *D. (D.) transversus*, new species, from the Road Canyon Formation was detected in this species.

Chonetids, as a rule, are variable, especially if a large collection of them is available for study, and this species is no exception. Variation is seen in the lateral extension of the hinge, some specimens having rounded points or extremities less angular than usual. Some specimens are not so strongly convex as usual, and the fold of the brachial valve in other specimens is somewhat broader and lower than that of the type. The development of the ears in the young is variable; they may be strongly emphasized by a fairly strong emargination of the lateral margin just anterior to the ear, or else the lateral margin is nearly straight but slopes strongly toward midvalve.

This species is fairly common in the Road Canyon Formation at USNM 707e but is generally rare elsewhere.

***Dyoros (Dyoros) attenuatus*, new species**

PLATE 481: FIGURES 1–10

Widely trapezoidal, hinge almost three times length; cardinal extremities mucronate; sides in-

dented and strongly oblique; deeply concavo-convex; anterior margin narrow and deeply indented; anterior commissure with strong dorsad fold. Posterior margin with 7 to 10 oblique spines. Surface smooth but in exfoliated condition finely but irregularly capillate.

Pedicle valve with lateral commissure gently and evenly convex; anterior commissure broadly domed, deeply indented medially and with sides nearly flat. Umbonal region swollen; sulcus originating just anterior to umbo, wide and deep and bordered by narrowly rounded plications; lateral slopes to cardinal extremities short and steep. Cardinal extremities well demarcated by sulci on outside of each plication. Ears rounded and mucronate.

Brachial valve deeply concave, most concave in median region just anterior to umbo; fold originating near midvalve broad and moderately elevated, bounded by deep sulci; ears concave and separated from median region by short oblique fold forming small fold on commissure.

Pedicle valve interior with short median septum but ridge anterior to septum not developed.

Brachial valve interior not known.

MEASUREMENTS (in mm).—From locality USNM 731, holotype 151990, and from AMNH 635, specimen 151989, respectively: length 10.0, 8.7; brachial valve length 8.9, 7.4; surface length 12.0, 11.0; hinge width 27.5, 24.6; midwidth 18.3, 14.4; height 3.6, 3.3; thickness 1.9, (?).

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler Member).

LOCALITIES.—AMNH 635, USNM 731.

DIAGNOSIS.—Attenuated *Dyoros (Dyoros)* with the hinge width almost three times the length.

TYPES.—Holotype: USNM 151990. Figured and measured paratype: USNM 151989.

COMPARISON.—This is the most attenuated species of *Dyoros (Dyoros)* known and is thus unlike all other described species. It is extremely rare; only two specimens are known.

***Dyoros (Dyoros) consanguineus* (Girty)**

PLATE 481: FIGURES 45–69; PLATE 482: FIGURES 1–5

*Chonetes consanguineus* Girty, 1929:409, figs. 8, 9.

*Dyoros consanguineus* (Girty) Stehli, 1954:312, pl. 19: figs. 9–12.

Shell thin, medium size for genus, wider than long, widest at hinge; ears prominent, pointed,

forming angle of 60° to 70°. Sides straight, oblique to slightly rounded, indented in some large specimens, anterior margin notched; anterior commissure narrowly uniplicate. Posterior margin with eleven short, oblique spines. Surface smooth.

Pedicle valve with moderately strong convexity in lateral profile; anterior profile with strongly bilobed median part and depressed ears. Umbonal region gently convex and with short, steep lateral slopes. Sulcus deep and narrow, originating at umbo and deepening to anterior margin. Flanks bounding sulcus narrowly and strongly rounded and with steep slopes. Ears small, not strongly demarcated.

Brachial valve having shallow concavity; umbonal region concave; fold originating near beak on umbo, narrowly rounded and becoming elevated anteriorly; areas bounding fold moderately concave; ears demarcated by low fold, usually flatly concave.

Pedicle valve interior with short septum anterior to apical callus; septum not extended anteriorly but its place taken by narrow ridge formed by narrow exterior sulcus. Diductor field short and wide. Inner surface finely papillose.

Brachial valve interior with small deeply excavated cardinal process; outer socket ridges small; prosocket ridges thin and short. Adductor dividing ridges delicate and not extended. Brevisseptum low, with few spines on distal extremity. Anterolateral and lateral margins of visceral region moderately fringed by spines.

MEASUREMENTS (in mm).—Brachial valve length of specimen 151946j, 10.0; of others, unmeasurable.

	length	sur- face length	hinge width	mid- width	height	thick- ness
USNM 728f						
151946a	14.8	18.0	28.6	21.0	6.6	?
151946b	13.0	14.0	23.8	19.6	4.5	?
151946c	13.0	14.0	23.3	20.5	5.1	?
151946d	12.0	13.5	24.2	18.0	6.0	?
151946e	9.7	11.5	20.2	14.0	4.1	?
151946f	8.0	9.0	14.7	11.9	2.7	?
151946g	7.3	8.0	14.0	12.0	2.0	?
151946h	12.3	14.0	20.3	18.2	3.7	?
151946i	11.4	13.0	23.0?	17.8	4.5	?
151946j	11.0	12.0	20.0	17.0	3.4	2.1
155141a	10.5	12.5	19.9	17.7	3.4	?
(lectotype)						

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation, Skinner Ranch Formation (Dugout Mountain, Poplar Tank, and Sullivan Peak members).

LOCALITIES.—Bone Spring: AMNH 628, 629, 631, 696; USNM 725c, 728e, 728f, 728h, 746. Dugout Mountain: USNM 732e. Poplar Tank: USNM 707ha. Sullivan Peak: USNM 722-l.

DIAGNOSIS.—Transverse and convex *Dyoros* (*Dyoros*) having a slitlike sulcus and narrow fold.

TYPES.—Lectotype: USNM 155141a. Figured paratype: USNM 155141b. Figured hypotypes: USNM 151946j-s, u, x, y; 153689. Measured hypotypes: USNM 151946a-j.

COMPARISON.—The deep and narrow sulcus on the exterior, combined with the absence of a median ridge in the pedicle valve, distinguish this species from all the others.

DISCUSSION.—This species exhibits considerable variation in such characters as the hinge and ears, the shape, the height, and the fold and sulcus. The cardinal extremities of many specimens are attenuated into long ears, usually well demarcated and resulting in fairly straight but strongly oblique, medially sloping sides. In others the sides are nearly straight and the ears are small, some approaching a right angle and in others forming small points. These specimens tend to have a more rectangular form than the ones with oblique sides. The variation in the form and shape of the ears may result in a somewhat narrower hinge but in many specimens the width of the hinge may be the same but the form of the ears different. The shape of the ears thus determines to a great extent the shape of the shell, whether strongly rectangular or more trapezoidal.

The height is variable, some specimens attaining considerable length before anterior growth starts in a dorsal direction. In many specimens dorsad growth of the anterior of the pedicle valve took place fairly early, with the result that these forms become more convex at an earlier stage than some of the larger ones.

The sulcus is narrow in some specimens but wider and deeper in others. This variation in the sulcus affects the fold, which varies in accordance with the sulcus. It also affects the plications bounding the sulcus; these are broad and low in the moderately sulcate forms but narrow and high in the forms with a wider sulcus.



*Dyoros (Dyoros) convexus*, new species

PLATE 482: FIGURES 6–32; PLATE 501: FIGURES 32–61

*Lissochonetes subliratus* Newell et al. (not Girty), 1953, pl. 21: fig. 6.

Large for genus, wider than long, maximum width at hinge; cardinal extremities acute and extended in young but narrowly rounded in adults, forming angle about 60° to 70°. Lateral margins varying from straight and oblique to concave oblique; anterior margin truncated and slightly indented medially. Anterior commissure narrowly uniplicate. Surface marked by growth lines and varices.

Pedicle valve evenly and fairly strongly convex in lateral profile, strongly convex in anterior profile, ears depressed. Umbonal and medial regions swollen; sulcus originating on umbo, narrow and deepening anteriorly, there fairly deep and indenting anterior margin slightly. Flanks bounding sulcus narrowly rounded and steep-sided. Ears usually well demarcated, commonly set off by abrupt

change of slope or shallow groove often indenting lateral margin. Interarea moderately long, orthocline to apsacline; pseudodeltidium short. Posterior margin with maximum (counted) of 13 oblique spines.

Brachial valve deeply convex in lateral profile with maximum concavity near midvalve; umbonal region concave; fold originating near midvalve, somewhat narrowly rounded, usually fairly conspicuous and bounded by deep grooves. Ears moderately concave, demarcated by narrow, strong oblique fold.

Pedicle valve interior with thick apical callus and short median septum; median ridge low but heightened by position on fold produced by exterior sulcus. Diductors flabellate. Interior strongly granulose.

Brachial valve interior with small cardinal process, deeply excavated; outer socket ridges small and inconspicuous; prosocket ridges slender; median ridge strongly elevated anteriorly, free edge spinose. Adductor field small. Anterolateral visceral

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 728							
151950a	14.9	12.5	20.5	27.3	19.9	7.0	4.3
(holotype)							
151950b	13.6	11.8	18.5	24.9	18.2	6.1	3.2
151950c	12.2	10.9	16.5	25.0	19.5	5.3	2.8
151950d	11.8	10.4	16.0	22.6	17.3	4.7	2.8
151950e	9.7	8.7	12.0	18.3	14.4	3.3	1.8
151950f	8.7	7.7	11.0	17.3	13.8	3.0	1.4
151950g	7.3	6.4	8.5	14.3	11.6	2.4	1.3
151950h	5.2	4.5	6.5	10.0	8.4	2.1	0.9
151950i	4.8	4.2	5.0	10.2	7.8	1.6	0.8
151950j	4.0	3.7	4.5	9.0	6.8	1.4	0.7
151950k	15.5	13.0?	19.0	29.6	21.5	6.6	?
151950l	17.4	14.5	24.0	28.7	21.6	8.0	?
151950m	17.6	14.6	24.0	30.3	22.4	8.1	?
151950n	17.4	14.3	23.5	27.6	21.0	7.4	?
151950o	15.5	13.6	21.5	26.5	21.5	6.9	3.7
151950p	14.5	13.0	18.0	23.4	18.7	5.5	2.9
151950q	14.1	11.9	13.0	20.7	18.6	5.7	3.7
151950r	9.8	8.7	12.0	16.0	14.0	3.2	2.0
151950s	10.1	9.3	12.5	15.5	14.0	3.8	2.9
USNM 732c							
153754a	16.7	13.6	25.0	24.5	18.7	9.7	5.8
153754b	12.6	11.3	16.0	24.4	17.0	5.8	2.5
153754c	13.0	11.4	18.0	21.2	15.2	6.5	3.1
153754d	12.0	10.3	16.5	22.2	14.1	6.2	2.1
153754e	11.0	10.0	14.0	18.4	14.2	5.0	2.6
153754f	9.3	8.3	12.0	17.5	13.3	4.1	1.8

area fringed and thickened in old adults.

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member), Word Formation (Appel Ranch Member and lenses between Willis Ranch and Appel Ranch members).

LOCALITIES.—Getaway: AMNH 21, 512, 519, 600; Moore 31; USNM 728, 730. Word: USNM 731m, 731u, 737b, 741p. Appel Ranch: USNM 714o. Lenses: USNM 732c, 737w, 742b.

DIAGNOSIS.—Large, strongly convex *Dyoros* (*Dyoros*) with narrow but shallow sulcus.

TYPES.—Holotype: USNM 151950a. Figured paratypes: USNM 151950c, g-l, o; 153690a-c; 153691; 153754a-j. Measured paratypes: USNM 151950b-s; 153754a-f. Unfigured paratypes: USNM 151905b, d-f, m, n, p-s.

COMPARISONS.—This species is most similar to *D. (D.) extensus*, new species, in having large extended ears but differs in proportions and the lesser development of the sulcus and fold. *Dyoros (D.) convexus* has a less extended hinge than *D. (D.) extensus* and the proportion of midwidth to length is generally larger. The species, in other words, is stouter, more rectangular, and with less oblique sides.

The outline of *D. (D.) convexus* is very much like that of *D. (D.) planiextensus*, new species, but the relative convexity of the pedicle valves is a ready means of separation. *Dyoros (D.) consanguineus* (Girty) is a fairly convex species but its slitlike median sulcus distinguishes it from other members of the genus. *Dyoros (D.) transversus*, new species, is too unlike *D. (D.) convexus* in outline and interior to make any confusion between the two possible.

This species has been usually regarded as referable to Girty's *Chonetes subliratus* but that species is a smaller form having completely different propor-

tions and coming from a much higher formation in the Guadalupe Mountains.

DISCUSSION.—Like other members of this genus *D. (D.) convexus* is a variable species. Of some interest is the occurrence of almost rectangular forms in which the hinge is only slightly wider than midvalve. Internally most of the features are like those of *D. (D.) extensus*. The median ridge of the pedicle valve is well developed and the fringed crescent on the side of the visceral region is strongly developed.

### *Dyoros (Dyoros) endospinus*, new species

PLATE 284: FIGURES 1-15

These specimens have the general form and outline of *D. (D.) extensus*, new species; the length to hinge width ratio is 0.50. The length to midwidth ratio, on the other hand, represents the outside limit for the species. In other words, the midwidth is wider than in specimens from the higher members of the Word Formation. Another exceptional feature of the Road Canyon specimens is the bizarre growths connected with the muscle fields of both valves. In the pedicle valve numerous spiny growths have a height well over a mm and appear in rows at the anterior margin of the diductor scars. Similar spiny growths appear on the slope from the ear trough to the muscle field and on the median ridge. In the brachial valve extravagant growths appear at the extremities of the adductor dividing ridges and on the anterior slope of the brevisseptum.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITY.—USNM 707e.

DIAGNOSIS.—Widely extended *Dyoros (Dyoros)* with strongly thickened and extravagantly endospinose interior.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 707e							
151917a	15.2	13.0	18.5	28.0	20.6	6.0	3.3
151917b	14.8	12.1	17.0	26.0	18.5	5.5	2.9
151917c	12.2	11.7	15.0	23.3	17.6	4.6	2.2
151917d	13.4	?	16.0	26.8	20.0	4.2	?
151917e	14.3	12.5	18.0	30.4	22.0	5.5	2.4
(holotype)							

**Types.**—Holotype: USNM 151917e. Figured paratypes: USNM 151917a, 151918a–d. Measured paratypes: USNM 151917a–d. Unfigured paratypes: USNM 151917f–z, aa–cc.

**Comparison.**—This is a widely extended species and therefore is comparable to *D. (D.) attenuatus*, *convexus*, *extensus*, and *transversus*, all new species, and to *consanguineus* (Girty). It is not so short and attenuated as the first species; it is more angular at the cardinal extremities, wider, and with a less deep fold and sulcus than *D. (D.) consanguineus*. *Dyoros (D.) convexus* is a deeper and more acutely angular species but narrower than *D. (D.) endospinus*. The common *D. (D.) extensus* is less thickened and spinose internally, has somewhat bulging sides but less pronounced ears than *D. (D.) endospinus*. The species most like *D. (D.) endospinus* is *D. (D.) transversus*, which is wider, more strongly angulated at the cardinal extremities, and has a more strongly thickened interior than the former.

*Dyoros (Dyoros) extensiformis*, new species

PLATE 483: FIGURES 1–10; PLATE 500: FIGURES 20–32

?*Chonetes subliratus* R. E. King (not Girty), 1931:63, pl. 10: figs. 7a–c.

Large, rectangular, hinge widest, and measuring about twice length at midvalve; ears large and prominent. Sides strongly indented in old shells to strongly oblique and straight in young ones. Anterior margin truncated and emarginate. Anterolat-

eral extremities narrowly rounded. Anterior commissure with broad and strong dorsad fold. Posterior margin with about seven oblique spines.

Pedicle valve evenly and gently convex in lateral profile; anterior profile forming broad gentle dome with flattened and depressed sides representing ears. Umbonal region slightly swollen; median region moderately swollen. Sulcus originating anterior to umbo near midvalve, broad and shallow; flanks bounding sulcus fairly broadly rounded and moderately swollen. Lateral slopes to posterolateral extremities short and steep; anterior slopes steeper than lateral ones. Posterolateral extremities strongly depressed and prominently flattened. Interarea moderately long, apsacline.

Brachial valve fairly deeply concave in median region, concavity extending to umbo and anterolaterally on each side of broad and low fold; posterolateral extremities moderately concave and demarcated by strong oblique folds extending from beak to about middle of lateral margin which is folded in dorsad direction. Interarea short, hypercline.

Pedicle valve interior with small teeth, strong apical callosity, and short median septum not extended anteriorly as ridge.

Brachial valve interior with small, excavated cardinal process and moderately long, oblique, moderately thick prosocket ridges. Adductor dividing ridges long and slender and with protruding an-  
teridium. Brevisseptum low, not extending posteriorly to antron. Visceral region not strongly thickened anterolaterally and moderately spinose.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702c							
151972a	12.4	11.0	14.5	25.8	19.7	4.1	2.3
(holotype)							
151972b	10.2	8.9	12.0	12.0	17.0	3.8	2.3
151972c	10.1	9.2	11.5	20.4*	16.9	3.6	1.8

**Stratigraphic Occurrence.**—Cathedral Mountain and Road Canyon formations.

**Localities.**—Cathedral Mountain: AMNH 500G; USNM 702b, 702un. Road Canyon: USNM 702c, 703a, 720d, 721o, 721r.

**Diagnosis.**—Extremely wide *Dyoros (Dyoros)* of low convexity with wide moderately deep sulcus and broad fold confined to anterior.

**Types.**—Holotype: USNM 151972a. Figured paratypes: USNM 151971a, b; 151972b, d, e. Mea-

sured paratypes: USNM 151972b, c. Unfigured paratypes: USNM 151971c-g; 151972c-f.

COMPARISONS.—This species can be compared directly to the species of widely extended hinge and low convexity such as *D. (D.) transversus*, *extensus* and *planiextensus*, all new species. Two other widely extended species, *D. (D.) concavus* and *convexus*, both new species, are too much higher than *D. (D.) extensiformis* for direct comparison.

*Dyoros (D.) extensiformis* is most like *D. (D.) transversus*, but is actually not so strongly transverse as that species and has more strongly differentiated ears than the Road Canyon species. These are demarcated on the brachial valve of *D. (D.) extensiformis* by low, oblique ridges which may indent the lateral margin, a feature not seen in *D. (D.) transversus*. The anterior margin of adult *D. (D.) transversus* is strongly emarginate medially, whereas that of *D. (D.) extensiformis* is only moderately indented. In addition to these exterior characters may be added the difference of the unusual spinescence of the brachial interior of *D. (D.) transversus*, a characteristic not seen in the other species.

*Dyoros (D.) extensiformis* differs from *D. (D.) extensus* in having lesser convexity of the pedicle valve, more strongly defined ears with the lateral margin more strongly notched anterior to the ears, deeper anterolateral depressions bounding the broad but lower fold, and steep umbonal slopes to the ears.

*Dyoros (D.) planiextensus* is larger and more convex than *D. (D.) extensiformis*, with a longer but narrow sulcus, a longer and narrower fold, and the ears not strongly differentiated from the shell body as they are in *D. (D.) extensiformis*.

DISCUSSION.—*Dyoros (D.) extensiformis* is represented by a small collection, for it is very rare at USNM 702c. Although great quantities of rock from this place were digested in acid only a few specimens of chonetids were found. The general resemblance of this species to *D. (D.) transversus* and its close proximity to it stratigraphically suggest that *D. (D.) extensiformis* may be the progenitor of that species. The collection is not large enough to indicate the directions of variation of this species.

### *Dyoros (Dyoros) extensus*, new species

PLATE 483: FIGURES 11-44

*Chonetes subliratus* R. E. King (not Girty), 1931:63, pl. 9: fig. 25, pl. 10: fig. 3.

Large for genus, hinge wide, about twice shell length. Cardinal extremities usually acute, commonly alate and having angle of  $50^{\circ}$  to  $65^{\circ}$  but varying farther. Lateral margins usually strongly oblique, straight to slightly concave; anterolateral extremities narrowly rounded; anterior margin nearly straight in some young to moderately bilobed in some adults. Anterior commissure with fold toward brachial valve varying from narrow to broad and barely perceptible. Surface marked by concentric growth lines and varices.

Pedicle valve in lateral profile with convexity increasing with age, adults fairly strongly convex but youthful shells, flatly convex; anterior profile varying from broadly and gently convex, median region flattened to lightly concave to medianly bilobed, ears strongly depressed. Beak small; umbo low, rounded, broad; sulcus variable, originating on umbo or anterior, widening and deepening anteriorly; flanks bounding sulcus varying from broadly to narrowly rounded. Ears usually well demarcated, moderately convex, depressed and set off by steep slope or shallow groove indenting lateral margin. Pseudodeltidium short, forming an elevated rim around delthyrium. Interarea moderately long, orthocline to gently apsacline.

Brachial valve moderately concave in lateral profile, deepest part located in posterior third; fold originating near midvalve, variable and usually well defined only in anterior third; fold bounded by oblique shallow depressions, these in turn separated from ears by low oblique fold; ears concave but shallow. Interarea short, hypercline.

Pedicle valve interior with apex plugged by callus; median septum short, elevated only anterior to callus, continued anteriorly to beyond midvalve as low, thin ridge. Diductor flabellate moderately strongly impressed. Teeth small.

Brachial valve interior with small cardinal process with deep anterior pit. Median septum buttressed posteriorly by low ridge; prosocket ridges weak; anterolateral areas thickened by taleolae, especially in old specimens.

## MEASUREMENTS (in mm).—

	<i>length</i>	<i>brachial valve length</i>	<i>surface length</i>	<i>hinge width</i>	<i>midwidth</i>	<i>height</i>	<i>thickness</i>
USNM 706c							
151915a	17.0	14.0	22.5	30.2	23.7	6.6	4.0
151915b	15.5	13.5	18.5	28.8	23.7	6.0	3.1
151915c	14.8	13.3	19.0	31.5	23.8	5.9	3.7
151915d	14.8	13.0	18.0	27.0	22.1	5.4	3.2
151915e	13.7	12.4	17.0	29.0	23.0	5.5	3.2
151915f	13.5	12.5	17.0	25.4	21.4	5.2	2.2
151915g	12.8	11.3	15.0	24.9	19.2	4.4	2.0
151915h	12.8	11.4	14.0	23.8	17.8	4.2	2.8
151915i	11.4	10.0	13.0	22.3	17.4	3.4	1.9
151915j	9.8	9.0	11.0	18.6	15.0	2.6	1.4
151915k	9.4	8.6	10.5	20.2*	14.2	2.9	1.4
151915l	9.8	8.8	12.0	20.4	15.0	3.5	1.8
151915m	8.9	8.3	10.0	16.9	13.6	2.4	1.6
151915n	7.4	6.6	8.5	14.9	11.4	2.2	1.2
151915o	5.7	5.0	6.0	10.8	8.5	1.4	0.8
151915p	14.8	13.5	17.5	26.5	22.1	5.0	3.0
151915q	14.1	12.6	16.0	28.4	22.0	4.5	3.6
151915r	11.4	10.0	13.0	22.1	17.7	3.6	2.3
151915s	9.2	8.7	11.0	19.0	14.6	2.8	1.6
151915t	7.6	7.0	8.5	14.4	11.6	1.9	1.3
151915u	6.5	5.8	7.0	13.0	11.0	1.9	1.2
151915v	5.2	4.8	5.5	9.7	7.8	1.2	1.0
153694a	16.0	14.0	21.0	32.5	22.8	7.8	4.1
(holotype)							
USNM 706							
151909a	15.8	?	20.5	29.6	22.3	6.0	?
151909b	16.5	?	20.5	32.5	25.6	5.4	?
151909c	17.1	15.0	21.5	33.8	25.0	6.0	?
151909d	16.2	?	20.5	31.2	25.0	4.8	?
151909e	12.4	11.0	14.5	24.4	17.3	4.0	?
151909f	13.6	?	15.5	24.5	19.7	4.0	?
151909g	9.8	?	11.0	19.9	15.3	3.1	?
151909h	10.6	9.5	12.0	19.7	14.6	3.6	2.0
151909i	5.8	5.0	6.5	11.2	9.3	1.7	0.9
USNM 706b							
151911a	14.8	12.7	21.5	32.3	24.6	9.2	4.3
151911b	13.8	11.8	17.0	29.8	22.9	6.0	3.2
151911c	12.6	11.2	15.0	23.7	17.8	4.2	2.4
151911d	8.6	7.7	10.0	17.3	13.8	2.5	1.5
151911e	7.8	6.9	8.5	16.2	12.0	2.2	0.9
151911f	6.2	5.5	7.0	12.7	10.3	2.1	1.0
151911g	16.1	14.8	19.5	31.6	24.2	6.4	3.2
151911h	15.0	13.6	18.0	29.4	23.7	4.8	2.5
151911i	15.5	13.7	19.0	25.8	21.9	5.7	3.1
USNM 715i							
151922a	15.2	13.7	18.5	28.6	21.4	5.0	2.2?
151922b	14.5	12.0	19.5	25.8	19.3	5.3	3.0
151922c	14.4	12.4	19.5	26.5	19.5	5.8	3.7
151922d	13.2	12.2	16.5	25.4	18.3	4.8	2.9
151922e	12.2	11.0	15.0	25.7	18.5	3.1	1.8
151922f	11.5	9.6	14.0	22.3	17.2	3.7	0.9?
151922g	9.1	8.0	11.0	18.4	14.3	3.4	1.6
151922h	6.4	5.6	7.0?	13.4*	8.8	2.0	0.9
151922i	4.9	4.3	5.5	9.9	7.1	1.6	0.7



STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member), Road Canyon Formation, Word Formation (China Tank, Willis Ranch, Appel Ranch members, and lens between the last two).

LOCALITIES.—Getaway: AMNH 496, 585, 600; USNM 732. Road Canyon: AMNH 503, 509; USNM 703, 703c, 703d, 707e. China Tank: USNM 706c, 706z, 713, 721p. Willis Ranch: AMNH 505; USNM 706, 706e, 723t, 724u, 735c. Lens: 706b, 742b. Appel Ranch: USNM 704, 706d, 714o, 715i, 716v, 719z, 722t, 727j.

DIAGNOSIS.—Wide-hinged, moderately convex, large *Dyoros* (*Dyoros*) with strong wide sulcus.

TYPES.—Holotype: USNM 153694a. Figured paratypes: USNM 151911d-f, 151914, 151915p, 151922c, 153694b-g, 153695a-c, 153696. Measured paratypes: USNM 151909a-i, 151915a-v, 151909a-i, 151911a-i, 151922a-i. Unfigured paratypes: USNM 151911a-c, e, g-i; 151915a-o, q-v; 151922a, b, d-i.

COMPARISONS.—*Dyoros* (*D.*) *extensus* resembles *D. (D.) planiextensus*, new species, but is a deeper form with much wider hinge and less quadrate outline. It also has a more pronounced fold and sulcus than *D. (D.) planiextensus*. *Dyoros* (*D.*) *consanguineus* (Girty) will not be confused with *D. (D.) extensus* because of its strong, deep, slitlike sulcus. *Dyoros* (*D.*) *convexus*, new species, is more retangular and has a less pronounced fold and sulcus and more convex pedicle valve than *D. (D.) extensus*. The peculiar interior and widely extended form, far more extended than *D. (D.) extensus*, distinguish *D. (D.) transversus*, new species, from the common Word species.

DISCUSSION.—*Dyoros* (*D.*) *extensus* is the commonest member of the genus in the Word Formation and occurs in all of the limestone members. As might be expected the specimens from each one of the Word limestone have characters of their own but the variations all fit within certain limits indicating that one species only is involved. The occurrences are discussed stratigraphically.

Willis Ranch Member: Typical members of the species occur in the upper part of this limestone but specimens from the lower part are thinner shelled and more delicate. They also tend to have a proportionately slightly narrower hinge.

This species is one of the commonest in the upper part of the Willis Ranch Member and occurs in abundance at USNM 706e. Specimens from this

locality are regarded as typical. They are generally moderately thick shelled and unusually well preserved. The median ridge of the pedicle valve is fairly strongly developed but the muscle scars are not well impressed. In the brachial valve the brevisseptum attains moderate height but is strongly spinose on its anterior face. Other features are generally moderately developed. Few gerontic forms appear at this level. A good series of young permits some remarks on development.

In the smallest specimens the ears are sharply pointed and the sides strongly oblique and straight. A specimen only 3 mm long measures 7 mm along the hinge, indicating that the younger specimens have a hinge wider proportional to the length than the adults. The change in proportion however seems not to be great. This relationship is near 0.4. A trace of the sulcus appears at about 5 mm.

Limestone lens between Willis Ranch and Appel Ranch members: Specimens from this limestone lens are typical in their outline and other exterior features, but the shell is somewhat thicker and old age characters are more prominent in the larger specimens. Brachial valves are thickened, with exaggerated spine fringes on the visceral region margins and the brevisseptum is strong and high at its anterior end.

Appel Ranch Member: Specimens from this limestone strongly suggest *D. (D.) convexus*, but the proportion of their length to hinge is closer to *D. (D.) extensus* than to the Guadalupe forms. The details of the interior are like those from the Willis Ranch Member. Some of the Appel Ranch specimens are strongly convex but they have a wide and strong sulcus quite unlike that of specimens from the Getaway Member of the Cherry Canyon Formation in the Delaware Mountains.

### *Dyoros* (*Dyoros*) *hillanus* (Girty)

PLATE 484: FIGURES 1-5; PLATE 498: FIGURES 49-57

*Chonetes hillanus* Girty, 1909:228, pl. 11: figs. 8-10.

This is another equivocal species, poorly understood because its type lot is inadequate and good supplemental material has not yet been found. The type lot consists of three specimens: a large pedicle valve (USNM 118518a), a smaller pedicle valve (USNM 118518b) and an impression of the dorsal side with some of the shell adhering (USNM

118518c). USNM 118518a (Girty, 1909, pl. 11: fig. 8–8b) is the best of the lot and is here designated lectotype for the species.

On the basis of these specimens the species may be characterized as follows: Trapezoidal, widest at hinge, measuring about twice length; cardinal extremities forming large ears; sides strongly oblique; anterior margin broadly rounded and slightly emarginate medially. Anterior commissure with gentle, broad dorsad fold. Number of posterior spines not certainly known, possibly ten.

Pedicle valve fairly strongly and evenly convex in lateral profile and most convex in posterior part; anterior profile broad dome with slightly concave, moderately sloping sides and deeply indented middle. Umbonal region slightly inflated. Sulcus originating just anterior to umbo, moderately broad and deep, indenting anterior margin. Flanks bounding sulcus forming strong, broad plications with moderately steep slopes to broadly depressed lateral areas. Anterior slope long, not so steep as lateral slopes. Interarea long.

Brachial valve deeply concave, deepest postero-medially; fold originating just posterior to midvalve, moderately broad and bounded by moderately deep troughs. Posterolateral extremities moderately concave, not well demarcated from median region.

MEASUREMENTS (in mm).—Extremities of lectotype damaged.

		<i>brach- ial valve length</i>	<i>sur- face length</i>	<i>hinge width</i>	<i>mid- width</i>	<i>height</i>
USGS 2926 (green)						
118518a (lectotype)	11.4	?	15.5	19.6*	17.6	4.0?
118518b	8.3	?	10.0?	16.0	14.6	2.4
118518c	10.1	8.7	?	19.8*	15.4	?

STRATIGRAPHIC OCCURRENCE.—Capitan Formation, Bell Canyon Formation (Lamar Member).

LOCALITIES.—Capitan: AMNH 847; USGS 2926 (green); USNM 739, 740. Lamar: AMNH 351, 430; USNM 725e, 728p, 738b.

TYPES.—Lectotype: USNM 118518a. Paratypes: USNM 118518b, c. Figured hypotypes: USNM 153743a-c.

DISCUSSION.—Few specimens have been taken from the Capitan Formation or its equivalents that can be identified with this species. Some specimens from the Lamar Member (USNM 728p), conform

to the type specimen as illustrated in plate 498. The pedicle interior is normal for the genus.

The exterior of this species needs clarification because Branson (1948:314), believing it to be costellate, assigned it to *Chonetina* (= *Chonetinella*). The types all show obscure radii but they have no uniformity and little strength. All the specimens were broken from solid rock with consequent injury to the external surface. It is believed that the radii are rather the result of the internal alignment of taleolae so common in the smooth chonetids than true exterior costellae. The silicified specimens from USNM 728p are smooth.

### *Dyoros (Dyoros) intrepidus*, new species

PLATE 484: FIGURES 6–32; PLATE 485: FIGURES 13–34; PLATE 498: FIGURES 58–62

Medium size for genus, wider than long, hinge widest, about 1.5 times length. Cardinal extremities acute, forming angle of 50° to 60°. Sides sloping obliquely and usually concave anterior to ear. Anterior margin rounded but indented slightly medially. Interarea moderately long, slightly apsacline to procline. Up to 10 spines on posterior margin. Beak small, umbonal region barely visible from dorsal side. Surface smooth; scattered, minute pits numerous.

Pedicle valve strongly and evenly convex in lateral profile, maximum convexity near midvalve; anterior profile narrow, medially indented dome with concave long sides. Umbonal region moderately swollen. Sulcus originating just anterior to umbo, narrow and moderately deep, extending and deepening to anterior margin. Sulcus bounded by narrow plications expanding anteriorly; lateral slopes short and steep; ears somewhat narrowly rounded. Pseudodeltium vestigial.

Brachial valve deeply concave, deepest from beak to about midvalve; low rounded fold beginning near midlength, separated by deep narrow extensions from median concavity. Ears well demarcated by low, oblique folds; ears gently concave.

Pedicle valve interior with small teeth; median septum rooted posteriorly in callus, highest posteriorly but reduced to fine thread anteriorly, terminating anterior to midvalve. Muscle field defined by oblique ridges and with flabellate diductor scars.

Brachial valve interior with quadrilobed cardinal

process partly covered by chilidial plates; antron deep; median septum strong, extending to beyond

midvalve and anteriorly serrate. Prosocket plates weak; anterior strongly granulose.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 731							
152794a	12.0	?	17.0	22.4	15.9	5.3	?
152794b	10.7	9.1	15.0	20.6	14.5	5.5	2.3
152794c	11.0	?	15.0	17.6	13.3	5.2	?
152794d	11.0	?	15.5	20.0	14.5	6.0	?
USNM 725g							
152795a	11.7	9.4	16.5	21.3	14.2	6.2	2.5
(holotype)							
152795b	10.8	?	14.5	22.0	14.3	5.8	?
USNM 725f							
152796a	10.8	?	15.0	20.2	13.7	5.3	?
152796b	9.2	7.6	12.5	18.0*	13.0	4.0	1.6
152796c	11.3	?	15.0	23.7	16.0	5.2	?
152796e	?	9.7	?	20.6	17.2	?	?

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler, Pinery, and Rader members).

LOCALITIES.—Hegler: AMNH 635; USNM 731, 732a, 740c. Pinery: AMNH 33, 375, 398, 435, 524, 528; USNM 733, 736. Rader: AMNH 388, 403, 410; USNM 725f, 725g, 725o, 740a, 740i, 740j.

DIAGNOSIS.—Medium-sized, wide-hinged *Dyoros* (*Dyoros*) with a narrow sulcus.

TYPES.—Holotype: USNM 152795a. Figured paratypes: USNM 152794a, b; 152795a, b; 152796b, c, e; 153697a, c; 153698a-g; 153744a-c. Measured paratypes: USNM 152794a-d; 152795b; 152796a-c, e. Unfigured paratypes: USNM 152794c, d; 152796a, d; 153697b.

COMPARISON.—Although this species is about medium size for a chonetid, it is relatively small for the genus. It is, however, much larger and less angular than *D. (D.) angulatus*, new species. The species most like it is *D. (D.) hillanus* (Girty), about which so little is known. At first it was thought that this species actually represented Girty's form but close comparison shows that the two are clearly unlike, for it is somewhat smaller and narrower than *D. (D.) hillanus*. It also has narrow ears, and the sides are concave anterior to the ears, in contrast to those of *D. (D.) hillanus*, and its lateral slopes are steeper on the flanks and more concave.

*Dyoros (Dyoros) magnus* Stehli

PLATE 482: FIGURES 33-45, 46-50?

*Dyoros? magnus* Stehli, 1954:312, pl. 19: figs. 13-15.

This is a rare species characterized by large size, low convexity, strongly rectangular form, and a length to width ratio near that of *D. (D.) consanguineus* (Girty). Its sulcus is less deep than would be expected for the normal dorsad growth of *D. (D.) consanguineus*. It thus appears to be a valid species of large size.

STRATIGRAPHIC OCCURRENCE.—Lower Bone Spring and Cibolo formations.

LOCALITIES.—Bone Spring: AMNH 628, 631; USNM 725c. Cibolo: AMNH 703.

TYPES.—Lectotype: AMNH 27295/1:2. Figured paratype: AMNH 27295/1:2. Figured hypotypes: USNM 151939, 153692, 153693. Figured specimen: USNM 151943.

DISCUSSION.—We obtained only a few specimens of this species from the Bone Spring residues, and all these proved to be smooth. We do not therefore agree with Muir-Wood's (1962:74) assignment of it to *Neochonetes*.

*Dyoros (Dyoros) planiextensus*, new species

PLATE 484: FIGURES 38-62; PLATE 485: FIGURES 38-51

Large, hinge forming widest part, equal to about 1.6 to 1.7 times length. Cardinal extremities acute

but ears poorly demarcated, forming angle of  $68^\circ$  to  $85^\circ$ . Lateral margins oblique, usually not indented. Anterior margin generally nearly straight, but slightly indented in some specimens. Anterolateral extremities strongly rounded. Anterior commissure usually with narrow fold toward brachial valve. Spines along posterior margin varying from 8 to 12.

Pedicle valve in lateral profile with gentle convexity; anterior profile broadly and gently convex, median part narrowly and deeply indented; ears not strongly depressed. Beak and umbo small and flattened; sulcus generally narrow, fairly deep, originating on umbo and extending to slightly indented anterior margin. Flanks bounding sulcus moderately and broadly convex. Slopes to ears gentle; ears not strongly demarcated and gently convex. Interarea moderately long, somewhat narrowly concave and strongly apsacline.

Brachial valve gently to flatly concave in lateral profile, maximum concavity near midvalve or slightly posterior. Fold originating in posterior third

usually narrowly rounded but not strongly elevated and best defined in anterior half. Ears gently concave and demarcated anteriorly by low, barely perceptible, oblique fold. Interarea short, hypercline.

Pedicle valve interior with posteriorly thickened median septum extended anteriorly as low ridge beyond midvalve and embellished by taleolae anteriorly; diductor scars broadly flabellate. Sub-peripheral region and posterolateral areas strongly pustulose. Deltidium short, but elevated.

Brachial valve interior with strong median septum continued posteriorly to pit under cardinal process, anteriorly fairly elevated and provided with strong spinelike taleolae. Chilidium well developed; cardinal process large and deeply excavated anteriorly and welded laterally and anteriorly to outer socket ridges. Prosocket ridges small and slender, commonly partially buried by callus. Anterolateral submarginal areas thickened, commonly elevated and with tuft of spines (taleolae).

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706b							
152064a	17.8	16.2	21.0	28.8	25.5	6.2	3.7
(holotype)							
152064b	16.2	15.8	18.5	29.8	24.0	5.0	3.5
152064c	16.0	15.0	19.5	25.9	23.2	5.8	3.9
153064d	14.3	13.6	17.0	25.7	21.3	4.4	3.0
152064e	12.0	11.0	13.5	21.5	18.0	3.2	2.2
152064f	11.3	9.8	12.5	18.7	16.8	2.9	2.4
152064g	7.7	7.0	8.0	14.0	12.0	2.0	0.7
152064h	6.4	5.8	6.5	11.3	9.7	1.7	0.8
152064i	9.5	8.0	10.0	16.0	13.0	2.8	2.1
162064j	12.2	11.0	14.0	19.0	17.0	4.0	3.0
152064k	14.2	13.0	17.0	21.9	19.6	4.7	3.8
152064l	15.0	13.5	17.5	22.6	21.2	5.0	3.9
152064m	16.0	14.3	19.5	24.6	22.7	5.3	4.2
152064n	16.3	14.4	20.5	24.8	21.8	6.2	5.1
152064o	14.0	12.8	16.0	24.5	21.0	4.2	2.8
152064p	14.6	13.0	17.5	21.8	19.2	5.3	3.9

STRATIGRAPHIC OCCURRENCE.—Word Formation (lens between the Willis Ranch and Appel Ranch members).

LOCALITY.—USNM 706b.

DIAGNOSIS.—Large *Dyoros* (*Dyoros*) with wide hinge, flatly concave brachial valves and poorly demarcated ears.

TYPES.—Holotype: USNM 152064a. Figured paratypes: USNM 152064d, e, g-i, m; 153699a-l. Measured paratypes: USNM 152064b-p. Unfigured paratypes: USNM 152064b, c, f, j-l, n-p.

COMPARISONS.—Compared to *D. (D.) extensus*, new species, with which it is found, *Dyoros (D.) planiextensus* may readily be distinguished by its

flatter valves, less oblique lateral margins, and poorly defined ears. In *D. (D.) extensus* the ears are strongly rounded and clearly set off from the body of the valve by oblique grooves on the pedicle valve and corresponding oblique folds on the brachial valve that strongly indent the lateral margins. Other features separate the two species; the sulcus of *D. (D.) extensus* is broader and deeper and the fold is broader. The two species are variable and some of the variations overlap; wide-hinged forms of *D. (D.) planiextensus* exist, but these are always less convex than the wide-hinged forms of *D. (D.) extensus*. Likewise narrow-hinged forms of the latter appear in the collection, but they are deeper than similar forms of *D. (D.) planiextensus*.

*Dyoros (D.) planiextensus* in its more alate forms is suggestive of *D. (D.) convexus*, new species, from the Guadalupe Mountains but differs in not having as great a height as that of the latter, having a flatter brachial valve and much less prominent and extended ears. *Dyoros (D.) hillanus* (Girty) as exemplified by the large silicified specimen USNM 151938, is like *D. (D.) planiextensus* in size, but has a narrower and deeper sulcus and a much more concave brachial valve, with a stronger median fold.

DISCUSSION.—*Dyoros (D.) planiextensus* as exhibited by large collections from USNM 706b, is only a moderately varied species. In its growth the shells are quite flat on the dorsal side but become more concave anteriorly, where the pedicle valve and the anterior of the brachial valve curve in a dorsal direction. The ears are variable as might be expected, being quite sharply angular in the young but becoming somewhat rounded and approaching a right angle.

This is the commonest chonetid at USNM 706b, where its occurrence among separated valves of many other species indicates a death assemblage.

### *Dyoros (Dyoros) robustus*, new species

PLATE 485: FIGURES 1–12

Large, widely rectangular, hinge widest part; cardinal extremities acute, forming angle about 67°; sides nearly straight but sloping strongly medially; anterior margin bilobed, median region strongly reentrant. Anterior commissure with dorsad fold. Posterior margin with 10 oblique spines.

Pedicle valve strongly and evenly convex in lat-

eral profile, maximum convexity near midvalve; anterior profile high, narrow dome with steep sides and deeply indented middle. Umbonal region swollen, slopes steep; median region greatly inflated. Sulcus originating on umbo, narrow and V-shaped, extending to front margin, indenting margin deeply. Plications bounding sulcus narrowly rounded, with steep descent into sulcus and steep outer slopes to margins; anterior slope steep. Ears convex, well demarcated by shallow sulcus at base of lateral slopes.

Brachial valve fairly deeply concave, deepest in median region; carinate fold originating at umbo and dividing concave area into two deep troughs. Ears gently concave and demarcated by oblique ridge forming slight marginal indentation.

Pedicle valve interior with small teeth and thick apical callosity, poorly developed short septum, and poorly developed median ridge; median fold formed by exterior sulcus, high and narrow. Lateral slopes and inner ear surfaces strongly granulose.

Brachial valve interior with deeply excavated cardinal process and narrow, oblique prosocket ridges. Adductor dividing ridges and anteridia not well developed; brevisseptum originating at antron, not strongly elevated anteriorly; strongly spinose on anterior slope. Anterolateral extremities of visceral disc strongly and narrowly thickened and strongly fringed by spines.

MEASUREMENTS (in mm).—From locality USNM 731 specimens 151992a (holotype) and b, respectively: length 18.2, 16.5; brachial valve length 14.9, 13.2; surface length 24.0, 19.0; hinge width 31.5, 26.7; midwidth 25.2, 21.0; height 8.6, 6.0; thickness unmeasurable.

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler Member).

LOCALITIES.—USNM 731, 732a.

DIAGNOSIS.—Large *Dyoros (Dyoros)* with deep, V-shaped sulcus and carinate fold.

TYPES.—Holotype: USNM 151992a. Figured paratypes: USNM 151992b, c. Measured paratype: USNM 151992b.

COMPARISONS.—This species, in its proportions and strength of sulcus, belongs to the *D. (D.) extensus* tribe. The great depth and V-shape of the sulcus is suggestive of *D. (D.) consanguineus* (Girty), but that species does not attain the great height of *D. (D.) robustus*. Another species of similar appearance is *D. (D.) convexus*, new spe-



cies, which has similar proportions but differs markedly in having a much more angular and deeper sulcus, more rounded bounding plications, sharper fold and much greater height.

*Dyoros (D.) extensus*, new species, is similar to *D. (D.) robustus* in its proportions, but is more laterally extended, never attains the great height of the Guadalupe species, and has a much less deep sulcus and broader, less carinate fold. *Dyoros (D.) hillanus* (Girty), as interpreted here, suggests *D. (D.) robustus*, but it is not so robust, has a much shallower sulcus, less well demarcated ears, less emarginate anterior margin, and much less height. *Dyoros (D.) planiextensus*, new species, like *D. (D.) extensus* does not have the deep sulcus or great height necessary for close comparison with *D. (D.) robustus*.

DISCUSSION.—This rare species is represented by few specimens. These, however, are so positive in their characters and so unlike any of the other species that they can be interpreted only as distinct species. The robust character and great height are distinctive, but the interior details do not offer anything of novelty in the genus.

### *Dyoros (Dyoros) subliratus* (Girty)

PLATE 484: FIGURES 33–37; PLATE 485: FIGURES 35–37

*Chonetes subliratus* Girty, 1909:228, pl. 20: figs. 4, 5 [6, 7 doubtful and immature]. [Not of R. E. King, 1931:63, pl. 9: fig. 25, pl. 10: fig. 3 (= *Dyoros (Dyoros) extensus*, new species).]

Girty (1909:228) based his species on four specimens, the largest of which is the holotype (USNM 118519a), designated in the legend to his plate (p. 578, pl. 20: figs. 4 and 4a). The three paratypes are immature forms. That illustrated in Girty's figure 5 (USNM 118519b) is smaller than the holotype but is clearly recognizable as the same species. The other two are very young forms that might pertain to this species or some other. A series would be needed to prove this point, but none is available.

Girty's holotype is about medium size for the genus with its midwidth greater than the length and with a wide hinge. The posterolateral extremities are drawn into prominent convex ears, separated from the shell body by a deep groove that forms a slight projection on the lateral margin. The fairly wide sulcus originates at the umbo, is moderately

deep, and indents the front margin. The flanks form narrowly swollen plications on each side of the sulcus and have precipitous sides. The anterior slope is steep. The lateral profile is fairly strongly convex and the anterior profile is a high, steep-sided and medially indented dome.

The paratype (USNM 118519b) appears to be definitely a young specimen clearly related to the holotype but not having attained the strong convexity of the mature shell. It is strongly folded and has the prominent ears of the holotype.

MEASUREMENTS (in mm).—Specimens USNM 118519a (holotype) and b (paratype), respectively: length 11.9, 8.6; surface length 17.0, 10.5; hinge width 21.8\*, 17.0\*; midwidth 15.0\*, 10.3; height 6.6, 3.3.

STRATIGRAPHIC OCCURRENCE.—Capitan Formation; Bell Canyon Formation (Pinery Member).

LOCALITIES.—Capitan: USNM 738b, 748a, 750a. Pinery: USGS 2930 (green).

DIAGNOSIS.—*Dyoros (Dyoros)* with strongly convex pedicle valve, wide hinge with narrow ears, and fairly wide sulcus.

TYPES.—Holotype: USNM 118519a. Figured paratypes: USNM 118519b; ?118519c, d. Figured hypotype: USNM 151960.

COMPARISON.—The considerable height, fairly wide sulcus, and small size of the species tend to distinguish it from all others. It is readily separated from *D. (D.) hillanus* by its much smaller size and different proportions. It differs from *D. (D.) angulatus*, new species, of the Glass Mountains, in its larger size, greater convexity and much less acute cardinal extremities.

DISCUSSION.—Girty's types are said to come from the "dark limestone" of the Capitan Formation (Pinery but "chiefly float"). This high but equivocal stratigraphic position makes it very unlikely that this species occurs in the Glass Mountains. All of the specimens in the King collection referred to this species belong elsewhere.

In *Dyoros (D.) subliratus* (Girty) we are confronted with a name that has received widespread but erroneous use. It has been identified in geographic areas where it is unlikely to occur and from parts of the column where it should not be expected. Furthermore, its stratigraphic level is not clearly known, and even with our large collections we were unable to identify the species except for a few specimens. All of the residues from the Bell Canyon

members produced no unequivocal specimens of the species. We are forced therefore to leave *D. (D.) subliratus* in an indefinite status. It must be re-discovered in the Capitan and collected in sufficiently large numbers to understand its growth and variation.

*Dyoros (Dyoros) tenuis*, new species

PLATE 486: FIGURES 1-27

Medium size to large for genus, wider than long, trapezoidal in outline. Hinge forming widest part; cardinal extremities acute but variable, forming angle of 65° to 70°. Sides varying from straight and sloping medially to moderately strongly concave; anterolateral extremities narrowly rounded. Anterior margin broadly truncated to slightly but broadly emarginated. Anterior commissure broadly folded in dorsal direction.

Pedicle valve unevenly and flatly convex in lateral profile with umbonal region and anterior forming

most convex parts. Anterior profile a broad, flattened dome with long, gently sloping sides. Beak inconspicuous; umbo slightly convex. Median region broadly flattened, with short slopes to cardinal extremities. Sulcus poorly defined and variable, originating generally near midvalve, broad, shallow, and in some specimens difficult to discern. Flanks bounding sulcus variable, usually appearing as low, broadly rounded ridges which terminate in anterolateral extremities. Anterior slope of sulcus short and steep. Interarea short, apsacline.

Brachial valve unevenly and flatly concave; concave region broadly triangular and bounded laterally by low flexure dividing concave median region from flattened to slightly concave posterolateral regions. Interarea short, anacline.

Pedicle valve interior with apical callosity and short median septum; ridge anterior to septum low and inconspicuous, anteriorly serrate. Muscle field large but lightly impressed. Posterolateral regions finely granulose.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706							
151996a	10.2	9.5	12.5	19.3	17.3	3.6?	2.2?
(holotype)							
151996b	10.4	9.8	12.0	19.0	16.6	2.9?	2.1
151996c	9.7	9.0	11.0	17.5	15.7	2.7	1.5
151996d	9.4	8.2	11.5	18.0	15.0	3.2	2.2
151996e	9.7	8.7	11.0	17.9	15.1	2.6	1.5
151996f	8.3	7.7	9.5	17.3	14.0	2.4	1.6
151996g	8.0	7.3	9.5	16.0	13.2	2.7	1.5
151996h	9.3	8.2	11.5	19.6	15.6	2.8?	1.4
151996i	5.3	4.7	6.0	10.6	9.0	1.6	1.1
151996j	4.1	3.9	4.5	9.4	7.6	1.2	0.8
151996k	3.8	3.4	4.0	8.3	6.8	1.0	0.7

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank and Willis Ranch members).

LOCALITIES.—China Tank: USNM 732s. Willis Ranch: AMNH 506; USNM 706, 724u.

DIAGNOSIS.—Transverse, rectangular *Dyoros* (*Dyoros*) having low convexity, thin shell, a broad shallow sulcus, and a truncated anterior margin.

TYPES.—Holotype: USNM 151996a. Figured paratypes: USNM 151996c, f, i-q. Measured paratypes: USNM 151996b-k. Unfigured paratypes: USNM 151996d, e, g, h.

COMPARISONS.—In its flattened form and broad sulcus, this species is unlike any other described. It resembles youthful forms of *Dyoros* (*D.*) *extensus*, new species, in form and extended hinge but is less convex, less laterally extended along the hinge, and more definitely rectangular. This species differs from *Dyoros* (*Tetragonetes*) *rectangulatus*, new species, which also has moderate convexity, in its more widely extended form, more oblique sides, and the less deep and wider sulcus and fold.

DISCUSSION.—This species is generally delicate

and thin-shelled, with definite, but not well thickened, interior details. The muscle marks of the pedicle valve are generally lightly impressed, and the anterolateral extremities of the visceral region are not greatly thickened but are definitely tufted with long granules or spines.

Variation is in the lateral extension of the ears, the breadth and depth of the sulcus of the pedicle valve, and the degree of folding of the brachial valve front. The species occurs in the lower part of the Willis Ranch Member, where it is abundant. Except for the great extension of the ears, this species is more like the type of the genus in general appearance than most of the Permian species.

*Dyoros (Dyoros) transversus*, new species

PLATE 486: FIGURES 28-67; PLATE 487: FIGURES 1-17; PLATE 501: FIGURES 1-4

Large for genus, hinge equal to twice length or slightly more. Maximum width at hinge; ears large, acute to mucronate, forming angle varying from 30° to 60°. Lateral margins strongly oblique, usually concave; anterior margin usually deeply indented medially. Anterior commissure usually with strong and broad fold toward brachial valve. Exterior smooth, except for concentric lines of growth and growth varices. Posterior margin with 12 spines on each side of the beak.

Pedicle valve moderately to strongly convex in

lateral profile, maximum convexity slightly anterior to midvalve. Anterior profile broadly lobed, median lobes narrowly convex, separated by deep indentation, the lateral lobes formed by ears, these strongly depressed. Umbonal region flat and smooth and with gentle slopes to ears. Sulcus variable, originating slightly posterior to midvalve, generally wide and deep. Flanks bounding sulcus strongly demarcated and narrowly rounded, with steep anterolateral slopes. Ears convex, rounded and greatly extended laterally, and in some specimens mucronate. Interarea, short, apsacline.

Brachial valve fairly deeply concave, deepest parts near midvalve and in troughs bounding fold. Ears concave, usually shallow and demarcated from median region by oblique ridges, these variably developed, strong in old adults. Fold originating at midvalve, elevating rapidly, subcarinate and fairly broad. Troughs bounding sulcus deep and prominent.

Pedicle valve interior with short, poorly developed apical median septum, extension anteriorly low and usually poorly defined. Diductor field well defined, flabellate, and with radial lines strongly thickened. Muscle field bounded posterolaterally by strong papillae; anterior part of muscle area common with scattered elevated taleolae; interior usually strongly papillose, extremely so in some specimens.

Brachial valve interior with small, deeply ex-

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 707e							
151980a	14.6	12.4	19.0	33.4	22.0	5.8	3.0
(holotype)							
151980b	14.8	13.3	18.0	31.2	20.6	6.0	3.0
151980c	14.2	13.0	16.0	30.0	21.0	3.9	2.1
151980d	11.5	10.0	13.0	28.9	20.3	4.3	2.1
151980e	9.5	8.9	10.0	25.6	16.8	3.0	1.5
151980f	7.8	7.0	9.0	19.9	14.0	2.5	1.3
151980g	7.3	6.5	8.0	19.0	13.2	1.9	0.8
151980h	10.2	9.1	11.5	28.6	18.0	3.7	1.6
151980i	7.8	7.3	8.5	20.0	13.2	2.8	1.0
151980w	11.6	10.4	13.0	32.3	16.0	4.0	2.0
USNM 703d							
151978a	14.6	13.2	17.0	34.1	23.6	5.6	3.0
151978b	12.7	11.8	14.0	28.0	19.6	3.7	1.7
151978c	10.8	10.0	12.5	25.0	18.0	3.4	2.1
151978j	15.3	14.3	19.0	32.3?	23.0	5.6	3.2
151978k	16.9	?	18.5	37.0	25.2	?	?

cavated cardinal process; outer socket ridges not strongly developed. Prosocket ridges partly buried, not strongly developed. Median septum low and thickened nearly to cardinal process posteriorly; anteriorly median septum greatly thickened at distal extremity by spiny taleolae uniting with those at posterolateral extremities of visceral area, forming wide W with outside arms incompletely developed.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation; Cibolo Formation (thin-bedded Zone of Udden).

LOCALITIES.—Road Canyon: AMNH 503; USNM 703c, 703d, 707e, 710u, 710z, 720d, 721j, 721s, 721z, 722e, 722g, 723a, 723x, 724a, 724c, 726d, 726e, 732j, 735a. Cibolo: 738–1, 738g.

DIAGNOSIS.—Unusually transverse *Dyoros* (*Dyoros*) with acute cardinal extremities and with the brachial valve having distal end of median septum joined to “fringed” margin of visceral area.

TYPES.—Holotype: USNM 151980a. Figured paratypes: USNM 151976; 151980c, e, h, m, n, s, t, w; 151997d; 153700b-f; 153701; 153702; 153703a; 153704a, b; 153705a-c; 153706a, b. Measured paratypes: USNM 151978a-c, j, k; 151980b-i, w. Unfigured paratypes: USNM 151980b, d, f, g, i-l, o-r, u, v; 151997a-c; 153700a; 153703b.

COMPARISON.—The exterior and interior of this species are so unusual as to separate it from all others. The shell is the most transverse of all the species except *D. (D.) attenuatus*, new species, and has a deep and narrow sulcus that deeply indents the median part of the anterior margin.

DISCUSSION.—This species, confined to the Road Canyon and Cibolo formations, is unusual in that its brachial interior has on the anterior of the visceral region a spiny fringe extended across the anterior trough onto the anterior of the median septum. In the pedicle valve a row of low spines hangs over the ridge separating the posterolateral margin of the muscle field from the ear trough. This is one

of the few species that shows the muscle scars in detail.

This species is found on both sides of the Glass Mountains in the Road Canyon Formation. Specimens from the western part of the mountains (USNM 707e) appear to average slightly wider and shorter than those from the eastern part of the mountains (USNM 703d). The species is not common at either locality.

*Dyoros (Dyoros) vulgaris*, new species

PLATE 42: FIGURE 16; PLATE 502: FIGURES 46–62

Small for genus, trapezoidal in outline, widest at hinge; sides oblique and nearly straight; cardinal extremities acute, forming angle of about 45°. Anterior margin truncated; anterior commissure with broad dorsad fold; posterior margin with about 7 spines on each side of beak.

Pedicle valve evenly and gently convex in lateral profile; broadly but moderately strongly domed in anterior profile; interarea fairly long, slightly curved, and apsacline. Umbonal region swollen; sulcus originating on umbonal region, variable from moderately strong to weak; flanks somewhat narrowly rounded and with fairly steep slopes to margin. Ears convex, depressed, sharply demarcated.

Brachial valve deeply concave in midvalve, concavity extending to umbonal region; ears marked off by low ridge; margin moderately reflected in dorsal direction. Interarea short, strongly hypercline. Median elevation low and short.

Pedicle valve interior with small teeth; median septum extending from delthyrial cavity nearly to anterior margin; inner surface strongly granulose to spinose. Apical callosity thick.

Brachial valve interior with wide cardinal process; antron variable from deep to shallow. Prosocket ridges slender; adductor dividing ridges and anderidia poorly developed. Brevisseptum variable. Flanks strongly endospinose.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 732j							
153750a	10.0	8.4	13.5	16.6	12.8	4.7	2.2
(holotype)							
153750b	11.8	10.0	15.5	18.6	14.8	5.0	2.3
153750c	10.3	8.5	15.0	18.1	13.6	5.5	2.6
153750f	10.0	8.7	14.0	15.7	13.8	4.6	2.0

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 732j, 736x.

DIAGNOSIS.—Small *Dyoros* (*Dyoros*), convex and with a poorly developed sulcus.

TYPES.—Holotype: USNM 153750a. Figured paratypes: USNM 153750b–d, g. Measured paratypes: USNM 153750b, c, f. Unfigured paratypes: USNM 153750e–h.

COMPARISON.—This species is most like *D. (D.) angulatus*, new species, in size but the latter is more strongly angular, with the ears more sharply demarcated by deeply oblique sides, and is more deeply sulcate.

DISCUSSION.—This is a variable species, especially its ears and sulcus. Although all the specimens are sulcate, the degree of depression varies from strong to gentle. The strongly sulcate specimens have narrowed flanks and are more suggestive of *D. (D.) angulatus* than the less strongly sulcate specimens. The specimens illustrated have the ears better preserved than the majority of specimens that have been rolled around before having been swept into the shell heaps of USNM 732j.

### *Dyoros (Lissosia)*, new subgenus

[Greek *lissos* (smooth)]

This subgenus is proposed for *Dyoros* shells that lack a sulcus on the pedicle valve in the young but only develop the sulcus in adult and old age stages. The brachial valve usually has a reduced or slight fold, seldom reaching the strong character of that of *Dyoros* (*Dyoros*). Internally the shells are like *Dyoros* (*Dyoros*) but do not develop the endospinosity usual in the genus except in very old age specimens.

TYPE SPECIES.—*Dyoros (Lissosia) concavus*, new species.

DIAGNOSIS.—Like *Dyoros* (*Dyoros*) but fold and sulcus conspicuously developed only in late adult stages.

COMPARISON.—The reduced fold and sulcus distinguish this subgenus from *Dyoros* (*Dyoros*). It is distinguished from *Leurosina*, new genus, which it resembles because of its reduced sulcus, in its generally laterally extended hinge and prominent ears, which, however, are not so strongly set off from the body of the shell as they are in *Dyoros* (*Dyoros*).

It differs from *Lissochonetes* Dunbar and Condra in its more robust shells and the greater depth of the pedicle valve.

DISCUSSION.—This subgenus is abundant at a few localities and has a fair stratigraphic range. It is generally represented by large species and is therefore conspicuous. Some specimens of *D. (L.) vagabundus*, new species, equal the largest of the species of *Dyoros* (*Dyoros*).

### *Dyoros (Lissosia) concavus*, new species

PLATE 487: FIGURES 18–46; PLATE 488: FIGURES 1–29; PLATE 502: FIGURES 44, 45

?*Chonetes subliratus* R. E. King (not Girty), 1931:63, pl. 10: figs. 4a, b [only].

Medium size for genus, widest at hinge, approximately twice length or slightly less. Cardinal extremities acute, generally sharply pointed, having angle of about 60°. Lateral margins strongly oblique, usually straight or slightly concave; anterior margin broadly rounded to truncate. Anterior commissure straight or with slight fold toward brachial valve.

Pedicle valve with lateral profile moderately and fairly evenly convex; anterior profile broadly convex but with steep sides to cardinal extremities. Beak small; umbo gently swollen but median region moderately inflated, moderately steep flanks. Sulcus indistinct; if present, broad and shallow, defined best at front; flanks moderately rounded. Ears convex, triangular, acute to submucronate. Pseudodeltitium short; spines numbering up to 11 on each side.

Brachial valve fairly deeply concave, maximum concavity in posterior third, anterior third to half gently convex to somewhat flattened or slightly concave at anterior margin. Ears gently concave and marked off by low, oblique fold. Anteromedian region marked by barely perceptible fold in many specimens, absent in others. Interarea short and hypercline.

Pedicle valve interior with thick apical callus, short but thick median septum with long, low, median ridge extending anterior to midvalve. Adductor patch heart-shaped; diductor scars flabellate. Lateral areas moderately strongly pustulose.

Brachial valve interior with small, deeply excavated cardinal process. Median septum not reaching



## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706e							
152149a	13.5	?	19.0	27.5	18.7	6.0?	?
152149b	12.7	10.9	17.0	24.5	17.8	5.5	3.1
152149c	12.4	10.6	16.5	21.8?	15.3	4.1	2.5
152149d	10.3	9.9	15.0	21.0	16.4	5.3	2.9
152149e	10.0	8.6	13.0	20.2	15.2	4.1	1.9
152149f	10.2	8.9	13.5	19.8	13.5	4.4	1.2
152149g	10.8	9.7	14.5	20.4	14.9	4.1	2.3
152149h	9.8	8.1	12.0	18.0	13.2	4.2	2.2
152149i	12.0	10.0	16.0	15.4*	14.4	5.7	3.7
USNM 706c							
152147a	15.9	13.4	22.0	28.8*	20.1	6.9	3.7
152147b	14.3	12.3	19.0	25.0*	19.0	5.9	2.8
152147c	14.3	12.0	20.0	24.0	19.0	6.4	3.7
152147d	13.8	11.5	19.0	23.7	18.6	6.1	3.3
152147e	12.8	10.7	18.0	20.5	16.7	5.8	3.7
152147f	10.8	15.0	15.0	21.8	15.0	4.9	2.7
152147g	11.5	9.6	15.5	20.3	15.5	5.0	2.9
152147h	9.6	8.3	12.5	15.5	13.0	3.8	1.9
152147i	13.7	11.6	20.0	20.9	16.7	6.6	4.6
USNM 706							
152144a	12.8	10.5	18.5	24.8	19.0	6.4	3.0
(holotype)							
152144b	11.8	9.9	16.0	21.8	17.3	5.6	2.2
152144c	12.7	11.0	16.5	23.2*	17.4	4.6	1.7
152144d	12.4	10.4	16.5	21.2	17.8	5.6	3.0
152144e	12.8	10.0	16.5	21.1	16.0	4.8	2.2
152144f	10.8	9.1	14.5	22.0*	16.0	4.2	2.2
152144g	9.5	8.0	11.5	18.0	14.5	3.1	1.4
152144h	8.4	7.5	10.0	18.2	13.3	2.7	1.1
152144i	6.5	5.7	8.0	12.8*	9.7	2.3	1.0

cardinal process; outer socket ridges long and thick; prosocket ridges weak. Anterolateral area strongly thickened by taleolae emphasized by strong curvature of valve.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation, Cherry Canyon Formation (Getaway Member), Word Formation (China Tank, Willis Ranch, and lens between Willis Ranch and Appel Ranch members).

LOCALITIES.—Road Canyon: USNM 707e, 721j, 724a. Getaway Member: Moore 31; USNM 732. Word: USNM 732s. China Tank: USNM 706c, 726r, 726s, 733q. Willis Ranch: AMNH 505; USNM 706, 706e, 718d, 723t, 723w, 724u, 735c. Lens: 706b.

DIAGNOSIS.—Wide-hinged, large *Dyoros* (*Lissosia*) having a deeply concave brachial valve.

TYPES.—Holotype: USNM 152144a. Figured paratypes: USNM 152147a, b, d, f, h; 152149e;

153706a, b; 153707a-c, e, f; 153708a, b. Measured paratypes: USNM 152144b-i; 152147a-i; 152149a-i. Unfigured paratypes: USNM 152144b-i; 152147c, e, g, i; 152149a-d, f-i.

COMPARISONS.—Because of its wide hinge this species needs to be compared only to *D. (L.) parvus* and *vagabundus*, both new species. It differs from the former in its greater size, the different outline, the great development of the ears, and the deeper brachial valve. It differs from *D. (L.) vagabundus*, in the greater narrowness of the ears, their stronger demarcation from the body of the shell, and the deeper brachial valve.

DISCUSSION.—This species, like *D. (L.) parvus*, develops differently from other Word *D. (Lissosia)*. The species suggests *Dyoros* (*Dyoros*) in its transverse form and the great development of the hinge, as well as the spines fringing the visceral region,

but the lack of a well-defined sulcus makes it impossible to place it in that species; an obscure and irregularly developed sulcus is present, but it is so variable as to defy description. In many specimens a shallow and narrow sulcus develops in the posterior or median portions of the pedicle valve only to be lost at the front, where no trace of it can be seen. Although a sulcus appears in some specimens, the brachial valve seldom develops a clearly defined fold. What fold does exist is generally located at the very anterior margin.

*Dyoros (Lissosia) concavus* occurs in several of the Word limestone members and in each of these it has definite characteristics. Specimens from the China Tank Member (USNM 706c) attain a larger size, have stouter shells than those from the higher limestones, and some of them exhibit radii. Specimens from low in the Willis Ranch Member (USNM 706) are more delicate than those of other levels and a few specimens are marked by radii like those of the lower limestone. Furthermore, the hinge of specimens from the lower part of the Willis Ranch are somewhat wider than that of the specimens from the China Tank, but have about the same proportions as specimens from the upper Willis Ranch. Specimens from the lens between the Willis Ranch and Appel Ranch members are solid, massive shells and more robust than those from the Willis Ranch Member.

*Dyoros (Lissosia) concavus* is fairly common at USNM 706 and 706c, but is rare at USNM 706b and 706e. At all these places it occurs with species of *Dyoros (Dyoros)* that probably, with the other associates, represent dead shell heaps.

*Dyoros (Lissosia) parvus*, new species

PLATE 488: FIGURES 30-45

*Chonetes permianus* R. E. King (not Shumard), 1931:62, pl. 9: figs. 1, 2 [not 3,4].

Small for genus, semielliptical in outline; wider than long, widest at hinge; cardinal extremities acute, forming angle varying between 60° and 75°. Sides oblique; anterior margin broadly rounded. Anterior commissure with narrow and faint fold in dorsal direction. Posterior margin with maximum of eight oblique spines on each side.

Pedicle valve unevenly convex in lateral profile, maximum convexity near midvalve but anterior third somewhat flattened. Umbonal region moderately inflated and with fairly steep slopes; median region inflated with steep lateral and anterior slopes. Sulcus originating on umbo, narrow and shallow, variable and not strongly defined in any specimens. Pseudodeltidium short and strongly convex.

Brachial valve deepest at midvalve, sides and anterior sloping gently toward midvalve. Fold narrow, low and inconspicuous. Cardinal extremities slightly concave, not clearly demarcated.

Pedicle valve interior with large teeth, thick apical callosity and stout median septum continued anteriorly to about midvalve. Lateral regions papillose.

Brachial valve interior with strongly excavated cardinal process, small prosocket ridges and adductor dividing ridges poorly developed. Brevisseptum low and inconspicuous. Anterior margins of visceral disc thickened and spinose only in adults.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 707e							
152154a	12.6	10.8	16.5	19.6	18.0	5.0	3.4
(holotype)							
152154b	11.0	9.6	15.0	19.4*	16.3	4.9	3.2
152154c	9.9	8.8	12.0	17.0	14.5	3.8	2.7
152154d	9.0	7.8	11.5	16.5	14.6	3.5	2.4
152154e	9.7	8.7	12.0	16.8	15.7	3.5	2.2
152154f	8.4	7.4	10.5	16.6	13.7	3.2	2.2
152154g	7.2	6.4	9.0	14.0	12.0	2.8	1.8
152154h	6.7	6.0	7.5	12.8	11.4	2.2	1.3
152154i	6.3	5.6	7.5	11.4	10.5	2.3	1.5
152154j	4.3	3.9	5.0	8.4	7.3	1.4	0.8

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation, Word Formation (Appel Ranch Member).

LOCALITIES.—Road Canyon: USNM 703d, 707e, 720d, 721j, 721r, 722g, 726d. Appel Ranch: USNM 719z.

TYPES.—Holotype: USNM 152154a. Figured paratypes: USNM 152154e, 153709a, b. Measured paratypes: USNM 152154b–j. Unfigured paratypes: USNM 152154b–d, f–j.

DIAGNOSIS.—Small, aberrant *Dyoros* (*Lissosia*) having a tendency to develop a poorly defined sulcus and slight fold.

COMPARISONS.—This is a small species of equivocal characters placed in this genus with some doubt. It is smaller than any other species now assigned, and combines some features of *Dyoros* (*Dyoros*) and *D.* (*Lissosia*), suggesting a definite link between the two. It differs from *Dyoros* (*Dyoros*) in the lack of well-defined folding in both valves and in the modest thickening and spinosity of the visceral region of the brachial valve interior. The indefiniteness, or lack of the positive characters of *Dyoros* (*Dyoros*), throws the species into *D.* (*Lissosia*).

*Dyoros* (*Lissosia*) *parvus* has a wide hinge and cardinal extremities drawn into ears. In these respects it is similar to another somewhat aberrant species, *D.* (*L.*) *vagabundus*, new species, but the latter has even more reluctant tendencies toward a sulcus on the pedicle valve than the former. Other distinctions appear in the different shape and the much greater size of *D.* (*L.*) *vagabundus*.

*Dyoros* (*Lissosia*) *parvus* is not likely to be confused with *D.* (*L.*) *concavus*, new species, which is a much larger species with more prominent ears and a deeply concave brachial valve.

DISCUSSION.—*Dyoros* (*Lissosia*) *parvus* is moderately rare in the bituminous part of the Road Canyon Formation, being commonest at USNM 707e. The species is variable in the development of the hinge and ears and also in the degree to which the fold and sulcus are formed. If the sulcus originates early in ontogeny it will be more noticeable than in an individual in which it gets a late start. Some specimens therefore show merely a broad anterior deflection, but others have a noticeable, if poorly defined, sulcus. The latter feature is never sufficiently developed to answer the requirements of *Dyoros* (*Dyoros*).

### *Dyoros* (*Lissosia*) *vagabundus*, new species

PLATE 488: FIGURES 46–59; PLATE 489: FIGURES 1–25

*Chonetes permianus* R. E. King (not Shumard), 1931:62, pl. 9: fig. 4.

Medium size for genus, wider than long, hinge approximately twice shell length; cardinal extremities produced into angular ears varying between 60° and 70°. Lateral margins moderately oblique, generally gently rounded. Anterior margin varying from fairly strongly rounded to truncate, depending on development of sulcus. Anterior commissure with broad dorsal fold. Posterior margin with maximum of 11 oblique, moderately long spines. Surface marked by concentric growth lines. Pseudodeltidium strongly convex; interarea moderately long, procline to orthocline.

Pedicle valve in lateral profile fairly evenly and gently convex; anterior profile broadly and gently convex with long lateral slopes. Umbonal region moderately swollen and midvalve moderately inflated. Sulcus variable, visible chiefly in anterior half, usually broad and inconspicuous but in few specimens fairly narrow; anterolateral flanks slightly swollen. Ears demarcated by change in posterolateral slopes, gently rounded, and usually angular.

Brachial valve moderately concave, maximum concavity near midvalve or posterior thereto; ears forming shallow troughs laterally, demarcated by broad oblique but gentle swelling bounding median concavity. Fold visible, in anterior half only, as broad but gentle flexure of anterior commissure. Interarea short, hypercline; chilidium short.

Pedicle valve interior with small callosity and short median septum; ridge anterior to median septum indifferently developed, generally low and inconspicuous. Muscle field roundly flabellate, moderately strongly impressed. Interior finely granulose.

Brachial valve with cardinal process low and of moderate size, deeply excavated in most specimens; prosocket ridges moderately developed; adductor dividing ridge short, inconspicuous, with anderidium not well individualized. Anterior lateral margin of visceral disc with fringe of strong and elevated taleolae. Brevisseptum low, ending in several strong spines.

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702b							
152166a	12.0	10.4	16.0	23.4	19.0	4.6	2.6
152166b	12.1	10.7	15.0	24.7	20.0	4.2	2.2
152166c	11.8	10.1	15.5	19.7?	18.0	4.0	2.3
152166d	11.0	9.7	14.0	20.0?	19.5	3.9	2.1
152166e	10.3	9.4	12.5	21.0	17.4	3.2	1.7
152166f	10.2	8.9	13.0	18.7	16.4	3.6	1.9
152166g	9.9	8.7	12.0	16.5	15.0	3.0	1.5
152166h	7.7	5.9	9.0	15.0	13.3	2.4	1.2
152166i	6.8	6.1	8.5	13.9	12.2	2.2	1.2
152166j	6.6	6.0	8.0	13.2	12.3	1.9	0.7
152166k	6.1	5.5	7.5	12.6	10.4	2.1	1.0
USNM 702							
152163a	13.2	11.0	17.0	25.7	22.6	5.5	3.0
(holotype)							
152163b	12.3	10.2	15.5	24.7	22.0	4.9	2.7
152163c	11.2	9.4	16.0	23.6	19.0	5.2	3.2

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation, Cathedral Mountain Formation.

LOCALITIES.—Bone Spring: AMNH 492, 592. Cathedral Mountain: AMNH 500, 500L 500N, 500X, 501, 504; USNM 702, 702a, 702b, 702ent, 702un, 703a<sup>1</sup>, 703b, 703bs, 707q, 708, 708u, 711q, 712o, 714w, 717e, 721u, 723k, 726u, 726x, 726y, 727p, 735b.

DIAGNOSIS.—*Dyoros (Lissosia)* with a wide hinge and angular cardinal extremities.

TYPES.—Holotype: USNM 152163a. Figured paratypes: USNM 152162a, b; 152163d–f; 152166a, e, i–k; 153710a–d; 153711a. Measured paratypes: USNM 152163b, c; 152166a–k. Unfigured paratypes: USNM 152163b, c; 152166b–d, f–h; 153711b.

COMPARISONS.—This species, in its outline and the possession of a wide hinge with acutely angular cardinal extremities, suggests *Dyoros (Dyoros)*; however, its pedicle valve is unfolded, except for a broad dorsad wave of the anterior margin, which in extreme cases produces a sort of sulcus, and its brachial valve does not possess a fold like that of *Dyoros (Dyoros)*.

*Dyoros (Lissosia) vagabundus* is similar in size to *D. (L.) concavus*, new species, but differs from it in having a less convex pedicle valve and much less well developed ears, which, in the latter are well demarcated by oblique swellings on the brachial valve and a slightly indented lateral margin just

anterior to the ear, whereas in neither valve of the former are the ears thus well demarcated.

*Dyoros (Lissosia) parvus*, new species, suggests *D. (L.) vagabundus*, but is a smaller shell with better defined ears and a tendency toward sulcation.

DISCUSSION.—Chonetids are not common in the Cathedral Mountain Formation but with the appearance of *D. (L.) vagabundus* in the upper part of the formation they become a more noticeable part of the fauna. *Dyoros (Lissosia) vagabundus* deviates from the characters of the genus as they are expressed in the overlying Word Formation in having an extended hinge. This species has a tendency toward the development of a poorly defined fold and sulcus in some specimens. The sulcus is represented by a distinct flattening and dorsad deflection of the anterior quarter or third of the pedicle valve with a corresponding dorsad deviation of the brachial valve. If this deflection takes place early in the growth of the individual, a poorly defined shallow sulcus develops. This, however, makes little impress on the brachial valve, which seldom shows even a poorly defined fold.

The interior of the valves is not well thickened except in old age. The median ridge is variable in the development of the pedicle valve, being well formed in some, but in others not appearing to be developed. In the brachial valve, the anterolateral part of the visceral region is slightly thickened and moderately fringed with taleolae.

*Dyoros (Tetragonetes)*, new subgenus

This name is proposed for a conspicuous group of chonetid shells that seem to characterize the later Leonardian and at least the part of the Guadalupian represented by the Word Formation and its equivalents. They have external and internal features that link them quite clearly to *Dyoros* (*Dyoros*) and yet at the same time, features that set them apart. Generally they are narrowly rectangular to squarish in outline, differing from *Dyoros* (*Dyoros*) in a great reduction of the ears. The lateral margins are generally nearly vertical to the hinge and usually slightly concave anterior to the ears, which are usually in the form of small points when well developed. The fold and sulcus are variable. Usually the former is fairly well developed but the latter somewhat less so. The two are not usually as strong as that of *Dyoros* (*Dyoros*) but in some species they are well developed indeed.

Internally the septa and endospines are generally not so strongly developed as in *Dyoros* (*Dyoros*), especially the thin-shelled species such as *D. (Tetragonetes) complanatus* and *planus*, both new species. In these, nevertheless, the well-developed septa prove to be a distinction between this Permian stock and *Lissochonetes* Dunbar and Condra. Some specimens have the anterior of the visceral disc well fringed by endospines as in *Dyoros* (*Dyoros*).

*Dyoros (Tetragonetes)* thus varies from *Dyoros* (*Dyoros*) in its lesser width compared to length, in the lesser development of ears, and generally a reduced development of the fold and sulcus, especially the latter.

Internally the septa and endospines are usually less positively developed. *Lissochonetes* in its compressed profile, thin shell and weakly developed interior details, may be likened to *Dyoros (Tetragonetes)*. *Lissochonetes*, however, is typically a wide-hinged form with strongly developed ears and strongly oblique sides, suggesting a thin-shelled *Dyoros* (*Dyoros*). Internally, the median septum of the brachial valve is typically reduced but not enough is known of other species to be sure of the universality of this feature.

TYPE SPECIES.—*Dyoros (Tetragonetes) quadrangulatus*, new species.

DIAGNOSIS.—Relatively narrow-hinged *Dyoros*

(*Dyoros*) with reduced ears, rectangular outline, and moderately developed interior details.

*Dyoros (Tetragonetes) auriculatus*, new species

PLATE 489: FIGURES 26–43

Medium size for genus, quadrate in outline, hinge widest part but midwidth only slightly greater than length. Cardinal extremities produced into sharply angular points or ears. Sides with deep indentation anterior to ears, moderately rounded anterior to indentation. Anterior margin broadly rounded to truncate. Anterior commissure with variable dorsad wave medially; lateral commissure strongly folded in dorsal direction. Posterior margin with 8 oblique spines on each side. Surface of some specimens freakishly marked by regular costellae, especially in posterior part.

Pedicle valve variably but generally moderately and evenly convex, maximum convexity near midvalve; anterior profile forming moderately high, narrowly rounded dome, flattened or slightly indented medially and with moderately steeply sloping sides. Umbonal region only slightly swollen; midregion fairly strongly inflated. Sulcus variable, originating just anterior to umbonal region, usually narrow and shallow, widening slightly anteriorly. Flanks bounding sulcus broadly rounded, anterior and anterolateral slopes steep. Umbonal slopes short and steep. Ears depressed. Interarea short, apsacline.

Brachial valve with triangular and deep medial concavity bounded laterally by strong oblique folds setting off narrowly but moderately concave ears from median concavity. Fold originating just posterior to midvalve, low and not conspicuous. Anterior slope steep. Interarea short, hypercline.

Pedicle valve interior with small but thick teeth having deep fossettes; apical callosity thick but median septum short; ridge anterior to median septum low and extended to beyond midvalve in old specimens. Inner lateral slopes granulose.

Brachial valve interior with small excavated cardinal process but thick, oblique prosocket ridges; adductor dividing ridges thick and long with slender anderidium well developed. Brevisseptum strong and elevated and spinose anteriorly, continued posteriorly as low thick ridge to antron. Visceral region thickened and spinose anterolaterally and laterally.



## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 728							
152180a	12.0	?	15.5	18.3	15.2	4.2	?
152180b	12.4	?	17.0	17.5	14.4	5.0	?
152180c	10.7	?	13.5	16.3	14.0	3.7	?
152180d	11.1	10.0	13.5	15.6*	13.5	3.9	2.1
152180e	10.2	9.0	13.3	16.7	13.7	3.7	1.8
152180f	10.1	8.9	13.5	16.6	13.3	4.3	2.1
(holotype)							
152180g	8.4	?	10.5	14.1	10.0	2.7	?
152180h	8.3	?	10.0	13.7	10.7	2.4	?

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member).

LOCALITIES.—AMNH 512, 519; USNM 728, 730, 732.

DIAGNOSIS.—Quadrangle, sharply auriculate *Dyoros* (*Tetragonetes*) with shallow median sulcus and broad indistinct fold.

TYPES.—Holotype: USNM 152180f. Figured paratypes: USNM 152180b, e, h, j, k, m, n; 153714. Measured paratypes: USNM 152180a–e, g, h. Unfigured paratypes: USNM 152180a, c, d, f, g, i, l.

COMPARISONS.—This species need be compared with only two other species, both of which are nearly square in outline. It differs from *D. (T.) quadrangulatus*, new species, in having narrower and sharper cardinal extremities, in having less convexity and a shallower and less pronounced sulcus on the pedicle valve. The fold of the brachial valve of *D. (T.) quadrangulatus* is stronger than that of *D. (Tetragonetes) auriculatus*. Inside the brachial valve the anterolateral extremities of the visceral disc region are more strongly spinose in *D. (T.) quadrangulatus* than in the Getaway species. The exterior of the Getaway species is frequently marked by distinct radial lines, an unusual feature in this genus.

*Dyoros (Tetragonetes) auriculatus* differs from *D. (T.) tetragonus*, new name for *Chonetes quadratus* (R. E. King), in having much more extended cardinal extremities and less pronounced sulcus on the pedicle valve. Comparison with this species is not satisfactory because so few specimens of it are known and its present status is somewhat uncertain.

DISCUSSION.—*Dyoros (Tetragonetes) auriculatus* is unusual in having fairly strong distant radial

markings on the pedicle valve. Generally the brachial valve is smooth or indistinctly costellate. This does not appear to be a weathering feature.

The young of this species are distinctly transverse but growth is greater anteriorly than laterally in early adulthood with the result that the shell tends to become more quadrangle with age and many specimens are nearly square. This species is rare in the sponge bioherm of the Getaway Member at locality USNM 728 (= AMNH 512). Here it occurs with several other species of chonetids in a probable death assemblage.

### *Dyoros (Tetragonetes) complanatus*, new species

PLATE 489: FIGURES 44–58; PLATE 499: FIGURES 1–17

Subrectangular in outline, generally moderately transverse, hinge usually slightly narrower or nearly equal to midwidth. Cardinal extremities generally slightly obtuse; sides gently rounded or nearly straight; anterior margin broadly rounded. Anterior commissure with narrow dorsal fold. Lateral commissure with prominent dorsal wave setting off the cardinal extremities. Surface smooth when fresh but finely capillate to costellate when weathered. Posterior margin with six spines on each side. Pseudodeltidium short.

Pedicle valve in lateral profile with variable but low to moderate convexity, anterior third somewhat flattened. Anterior profile low, broad and domelike, with long, moderately steep, lateral slopes and slightly indented crest. Umbonal region slightly swollen and with short slopes; median region moderately inflated. Sulcus originating on umbo, narrow

and shallow, widening only slightly to margin. Flanks somewhat narrowly but moderately swollen and with steep anterior slopes. Posterolateral extremities rounded but depressed. Interarea short, orthocline to anacline.

Brachial valve gently to moderately concave and deepest at umbo. Fold prominent but low, originating about one-third length from beak and widening to margin; flanks forming narrow troughs bounded posterolaterally by flattened to slightly concave cardinal extremities. Interarea short, hypercline; chilidium short and strongly convex.

Pedicle valve interior with moderate apical callus and short median septum extending anteriorly to

beyond midvalve as fairly strongly elevated ridge. Teeth small, oblique. Muscle field poorly defined. Interior finely granulose.

Brachial valve interior with small, deeply excavated cardinal process and short anterolaterally directed, poorly developed prosocket ridges. Adductor dividing ridges short and slender; adductum obscure. Brevisseptum long and slender, extending anteriorly to anterior margin of visceral region and posteriorly to antron, there thickened and widened by adventitious shell, thus uniting prosocket ridges and adductor dividing ridges. Visceral region strongly granulose and not marginally thickened or spinose in adults.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
Moore 31							
153712a	12.8	12.2	14.0	17.5	18.0	3.7	2.5
(holotype)							
USNM 732							
152017a	10.5	9.7	11.5	14.2	14.6	2.5	1.4
152017b	11.2	10.1	14.0	11.8*	13.7	3.5	2.6
152017c	10.4	9.2	12.5	12.5	13.3	3.4	2.2
152017d	10.7	9.7	12.5	12.4	13.8	3.0	2.5
152017e	9.8	8.7	10.5	12.6	13.5	2.4	2.1
152017f	7.6	7.0	8.5	9.7	10.5	2.0	1.6
152017g	7.0	6.2	8.0	8.0	9.4	2.2	1.4
152017h	6.6	6.0	7.5	8.7	9.0?	2.2	1.2
152017i	4.6	4.2	5.0	6.7	6.8	1.6	1.1
152017j	12.4	?	15.0	15.5	17.0?	4.0	?
Moore 31							
152022	12.8	11.8	15.0	17.6	17.8	3.3	2.7

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member).

LOCALITIES.—AMNH 21, 496, 519, 600; Moore 31; USNM 730, 732.

DIAGNOSIS.—Thin-shelled *Dyoros* (*Tetragonetes*) with subdued sulcus and fold and nearly flat brachial valve.

TYPES.—Holotype: USNM 153712a. Figured paratypes: USNM 152017a, b, d, f, i, k–m; 153712b; 153713a, b. Measured paratypes: USNM 152017a–j; 152022. Unfigured paratypes: USNM 152017c, e, g, h, j.

COMPARISONS.—The flatness of the brachial valve of this species limits comparison to a few similar forms. It is suggestive of *D. (T.) planus*,

new species, but that species has a more transverse shell, a more convex pedicle valve with more poorly defined sulcus than that of *D. (T.) complanatus*. It is about the same size as *D. (T.) quadrangulatus*, new species, but the pedicle valve of the latter is more convex, the brachial valve is more concave, and the sulcus is much more strongly developed.

The exterior form of *D. (T.) complanatus* is like that of *D. (T.) solidus*, new species, which is a thicker and wider shell with much more strongly developed fold and sulcus and a more concave brachial valve.

*Chonetes kaibabensis* McKee is a thin-shelled form of about the same size and proportions as the Guadalupe species but is only slightly folded and

the pedicle valve is lower in convexity than *D. (T.) complanatus*.

DISCUSSION.—This is a rare species in the Get-away Member of the Cherry Canyon Formation. Specimens showing good details of the interior show the pedicle valve to have a low median ridge extending to beyond midvalve. The brachial valve is characterized by a deep antron under the cardinal process bounded by short but strongly oblique prosocket ridges which are somewhat thickened and form a small chamber on the inside of these ridges. Near their anterior end the adductor dividing ridges appear and are moderately well developed. The brevisseptum originates within the chamber formed by the prosocket ridges and adductor ridges and extends anteriorly nearly to the front margin.

*Dyoros (Tetragonetes) giganteus*, new species

PLATE 497: FIGURES 31–35; PLATE 499: FIGURES 18–32

Large, compressed, subrectangular in outline, hinge equal to or slightly greater than midwidth; length about two thirds midwidth. Cardinal extremities forming sharp points. Sides nearly straight or moderately rounded and indented just anterior to small ears. Anterior margin truncate. Anterior commissure with broad dorsal fold.

Pedicle valve very gently but unevenly convex in lateral profile, greatest convexity in anterior half; anterior profile forming broad and gentle curve with gently sloping sides. Umbonal region gently swollen and with short slopes; median region slightly swollen. Sulcus defined in anterior third, broad and shallow, originating at edge of anterior slope. Flanks gently swollen. Interarea short with convex pseudodeltidium. Posterior margin with 10 fairly erect (about 60°) spines on each side of beak.

Brachial valve broadly and gently concave, maximum depression in posteromedian half; anterior quarter to half elevated into broad, gentle fold; posterolateral areas flattened and demarcated from central concave area by low, barely perceptible, oblique fold.

Pedicle valve interior with thick apical callosity, very short median septum not extended anteriorly as low ridge; teeth large and strongly oblique. Muscle field broadly flabellate; adductor field small,

with two low rows of taleolae extending anterior to it, and dividing diductor scars. Lateral regions finely pustulose.

Brachial valve interior not well known but with small, deeply excavated, cardinal process and short prosocket ridges. Adductor dividing ridges and anderidium slightly developed; brevisseptum greatly reduced.

MEASUREMENTS (in mm).—Thickness of holotype 0.7; of others, unmeasurable.

	<i>brach- ial valve length</i>	<i>sur- face length</i>	<i>hinge width</i>	<i>mid- width</i>	<i>height</i>	
USNM 702b						
152031a	19.0	17.4?	20.5	31.4	29.3	4.0
152031b	18.9	17.8	20.0	28.3	27.5	?
152031c	19.1	17.9	20.0	29.6?	29.0	?
USNM 702						
152029	15.2	14.1	16.5	26.0*	23.7	3.6
USNM 708u						
152032a	15.2	14.3	15.5	22.4?	21.4*	2.7
(holotype)						

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain Formation, Word Formation (Willis Ranch Member).

LOCALITIES.—Cathedral Mountain: USNM 702, 702b, 708u, 711q, 721u, 726u. Willis Ranch: USNM 735c.

DIAGNOSIS.—Large *Dyoros (Tetragonetes)* with length about two-thirds the midwidth and with thin body cavity.

TYPES.—Holotype: USNM 152032a. Figured paratypes: USNM 152031a; 152032b, c; 153736a, b; 153745; 153746. Measured paratypes: USNM 152029; 152031a–c. Unfigured paratypes: USNM 152031b, c.

COMPARISONS.—In its adult form this species is unlike any other assigned to this genus. The young as well as adults are extremely thin and readily differentiated from any other species.

DISCUSSION.—This species is one of the rarest in the Glass Mountains. It is known from few localities; one locality (USNM 708u) contained only a few loose pieces, the exact stratigraphic position of which are not known although their general position in the sequence is known. Unfortunately the only knowledge of the brachial valve interior is from an immature valve.

*Dyoros (Tetragonetes) lateralis*, new species

PLATE 499: FIGURES 33-37

Medium size for genus, transversely rectangular in outline, with slightly concave but nearly vertical sides; ears small; forming angle of  $95^\circ$  with posterior margin; anterior margin moderately indented medially; hinge widest part; anterior commissure with broad dorsal flexure; surface smooth. Pedicle valve interarea orthocline; brachial valve interarea hypercline.

Pedicle valve gently and evenly convex in lateral profile, maximum convexity near midvalve; anterior profile broad low dome with deep median depression and short steeply sloping sides. Umbonal region moderately swollen; sulcus originating just anterior to umbo, broad and moderately deep especially at anterior. Flanks bounding sulcus broad and moderately swollen; posterolateral slopes short and steep. Ears gently convex.

Brachial valve broadly concave, most concave just anterior to beak, becoming less concave anterolaterally; fold low originating about one-third length anterior to beak, broad and low at anterior margin. Ears gently concave, small.

Interior unknown.

MEASUREMENTS (in mm).—From locality USNM 711q, specimens 152798a (holotype) and b (paratype), respectively: length 13.7, 13.6; brachial valve length 11.0, (?); surface length 17.0, 18.0; hinge width 19.6?, 20.3\*; midwidth 18.3, 19.6; height 5.1, 4.6; thickness 2.4, (?).

STRATIGRAPHIC OCCURRENCE.—Cathedral Mountain and Road Canyon formations.

LOCALITIES.—Cathedral Mountain: USNM 707q, 711q, 723p. Road Canyon: 721r.

DIAGNOSIS.—Transversely rectangular *Dyoros* (*Tetragonetes*) with moderately deep sulcus and fairly strongly swollen flanks.

TYPES.—Holotype: USNM 152798a. Unfigured, measured paratype: USNM 152798b.

COMPARISON.—This species is similar to *D. (T.) quadrangulatus* and *solidus*, both new species, but although wider than either of them, is definitely assignable to *Tetragonetes* because of its nearly vertical sides and small ears. It differs from *D. (T.) subquadratus*, new species, which is also transversely rectangular, in its broader flanks bounding a somewhat less deep sulcus and its definitely more subdued fold and deeper brachial valve. This is an

uncommon species and none of the specimens reveal the interior of either valve.

*Dyoros (Tetragonetes) planus*, new species

PLATE 499: FIGURES 38-65

Medium size for genus, wider than long, hinge usually forming maximum width; cardinal extremities extended into minute points, or ears; lateral margins gently rounded but usually indented just anterior to small ears; anterior margin gently rounded to slightly emarginate medially. Anterior commissure with shallow, broad dorsal fold. Posterior margin with eight oblique spines on each side.

Pedicle valve moderately but unevenly convex, posterior half flattened and anterior half bulging slightly; anterior profile broadly convex, with short steep sides, median region faintly indented. Umbonal region flattened; posteromedian region flattened and with long gentle slopes to cardinal extremities; anteromedian region moderately swollen. Sulcus shallow, narrow, broadening anteriorly, not well defined, originating just posterior to anterior slope. Flanks bounding sulcus moderately swollen, lateral and anterior slopes steep. Ears small and rounded. Pseudodeltidium prominent and strongly convex. Interarea short, apsacline.

Brachial valve flatly concave, deepest in posterior half; fold originating near midvalve, broad and gentle and bounded by shallow flanking troughs; posterolateral regions slightly concave, demarcated by a low, flat fold. Chlidium and interarea short, latter hypercline.

Pedicle valve interior with broad delthyrium and low apical callosity. Median septum short, continued anteriorly to beyond midvalve as low, threadlike ridge. Muscle field flabellate.

Brachial valve interior with broad and spreading cardinal process anteriorly deeply excavated; prosocket ridges short; adductor dividing ridges strong but not continued anterior to anderidium; anderidium well developed and distally protuberant. Brevisseptum with distal extremity elevated and moderately spinose but posterior continued as low ridge to just anterior to antron. Lateral and antrolateral margins of visceral region moderately thickened and with small, inconspicuous spine fringe.

STRATIGRAPHIC OCCURRENCE.—Middle to Upper Cathedral Mountain Formation.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 711q							
152008a	12.3	11.3	14.5	16.4	17.0	4.6	3.2
152008b	11.2	10.3	13.5	16.9	15.9	4.5	3.3
(holotype)							
152008c	10.7	9.7	13.5	15.9	15.9	4.1	3.0
152008d	11.5	10.6	12.5	16.8*	15.9	3.2	2.6
152008e	9.2	8.7	10.0	15.4	14.2	2.1	1.4
152008f	8.3	8.0	9.0	13.6	12.9	1.5	0.8
152008g	8.2	7.9	8.5	12.0	11.5	1.7	0.8
152008h	6.1	5.6	6.5	8.4	7.9	1.6	1.0

LOCALITIES.—USNM 711q, 711r, 717g, 721u, 723p, 726y.

DIAGNOSIS.—Moderately convex *Dyoros* (*Tetragonetes*) with brachial valve nearly flat.

TYPES.—Holotype: USNM 152008b. Figured paratypes: USNM 152008a, c, e, h–j, l–n. Measured paratypes: USNM 152008a, c–h. Unfigured paratypes: USNM 152008d, f, g, k.

COMPARISONS.—This species compares best with *Dyoros* (*T.*) *solidus*, *quadrangulatus*, and *complanatus*, all new species. It differs from the first in having a less strongly developed sulcus and shorter, less conspicuous fold. It is distinguished from the second in having a less well developed fold and sulcus and in having a much flatter brachial valve, and it is more strongly convex than the last, as well as being wider along the hinge and having the brachial valve less concave.

DISCUSSION.—This species is rather rare at USNM 711q from which most of the specimens in the collection were taken. There it occurs in limy lumps in a shale matrix associated with a bryozoan bioherm. The interior of this species is similar to that of *D. (T.) complanatus* because both of the species have thin shells and similar proportions. The median ridge of the pedicle valve is much reduced and the position of the short median septum is represented by a slight elevation at the posterior of the ridge. Inside the brachial valve the thickening and disposition of the prosocket and adductor dividing ridges are the same as those of the Guadalupe shell, producing a five-rayed pattern with the brevisseptum. Unlike *D. (T.) complanatus*, anterolateral extremities of the visceral region of the Leonard shell are slightly thickened and the

granulation moderately coarse.

Very youthful specimens of this species are delicate. A pedicle valve 5 mm wide at midvalve has three spines on each side of the beak and only the short septum just anterior to the apical callosity is developed. The median ridge has not formed. A brachial valve of the same width has the prosocket ridges and cardinal process fused to make a broad inverted V. Other ridges and the brevisseptum have not yet formed. The granulation of both valves is coarse and that of the brachial valve is definitely radial.

*Dyoros (Tetragonetes) quadrangulatus*, new species

PLATE 490: FIGURES 1–19; PLATE 492: FIGURE 1

*Chonetes quadratus* R. E. King, 1931:63, pl. 9: figs. 7, 11? [not figs. 8, 9, 10].

Medium size for genus, slightly wider than long, hinge forming widest part. Cardinal extremities forming small pointed ears having angle of 65° to 90°. Sides indented just anterior to ears, otherwise nearly straight or slightly convex. Anterolateral extremities narrowly rounded; anterior margin truncated to slightly emarginate medially. Anterior commissure with slight, narrow to moderately broad fold toward brachial valve. Surface marked by concentric lines of growth.

Pedicle valve evenly and moderately convex in lateral profile; anterior profile strongly and somewhat narrowly domed and medially indented. Beak small; umbo moderately inflated, slopes steep. Sulcus variable, originating on umbo and extending



to margin, generally narrow and deep but varying to moderately broad and shallow. Flanks bounding sulcus narrowly rounded and with steep sides. Ears convex but depressed and inconspicuous. Interarea moderately long, orthocline. Spines short, oblique, eight to eleven on each side.

Brachial valve moderately deep in lateral profile and deepest slightly posterior to midvalve. Fold short, narrowly rounded but low and inconspicuous, originating near midvalve. Ears shallow, well demarcated by oblique fold. Interarea short, hypercline.

Pedicle valve interior with thick teeth and short,

stout median septum anterior to apical callus. Median ridge extending anteriorly from septum to beyond midvalve; ridge low but emphasized by interior fold produced by narrow, exterior sulcus. Inner lateral walls steep; interior strongly pustulose; pustules radially arranged. Diductor scars flabellate.

Brachial valve interior with moderately large and deeply excavated cardinal process; brevisseptum not reaching cardinal process in young but produced posteriorly almost to cardinal process in old specimens, anteriorly spinose. Anterolateral tuft of taleolae strong in adults and old specimens.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 715i							
153715a	14.0	11.9	18.0	18.2	16.6	7.3	2.3
(holotype)							
152187a	14.0	?	17.5	19.0?	18.3	4.2	?
152187b	14.2	?	21.0	21.2*	18.0	6.6	?
152187c	13.6	?	19.5	18.4	17.1	6.0	?
152187d	14.2	12.7	17.5	18.5	16.6	5.7	1.8?
152187e	13.2	?	19.0	20.0	17.5	5.4	?
152187f	13.0	?	19.0	19.2	15.4	6.0	?
152187g	12.8	11.0	17.0	18.2?	16.1	5.5	3.0
152187h	11.7	10.2	15.0	18.0?	15.0	4.8	2.0
152187i	11.7	?	15.5	15.8	14.3	6.0	?
152187j	9.6	8.5	11.5	15.1	12.5	3.0	1.5?
152187k	9.0	?	10.0	14.0	10.8	3.5	?
152187l	7.8	?	9.0	13.6	10.8	3.0	?
152187m	7.8	?	9.5	14.2	10.7	2.8	?
152187n	6.6	?	8.0	11.9	9.2	2.7	?

STRATIGRAPHIC OCCURRENCE.—Word Formation (Appel Ranch Member).

LOCALITIES.—Appel Ranch: USNM 704, 706d, 715i, 719z, 722t, 727j.

DIAGNOSIS.—Subquadrate convex *Dyoros* (*Tetragonetes*) with small ears.

TYPES.—Holotype: USNM 153715a. Figured paratypes: USNM 152187b, f, k; 153715b-d, f; 153722. Measured paratypes: USNM 152187a-n. Unfigured paratypes: USNM 152187a, c-e, g-j; 153715e.

COMPARISONS.—The quadrate form and small ears distinguish this species from other *Dyoros* (*Tetragonetes*) except *D. (T.) tetragonus*, a new name for *Chonetes quadratus* King. The latter

differs from the Word species in having a lower and less convex umbonal region, shallower and less pronounced sulcus on the pedicle valve, and more strongly demarcated ears.

*Dyoros (Tetragonetes) quadrangulatus* is also similar to *D. (D.) auriculatus*, new species, but that species has more pointed and prominent ears and the median sulcus is less well-defined; it commonly has, furthermore, sporadic radii on the pedicle valve, a rare character in the Glass Mountains species. For comparison with *D. (T.) wordensis* see under that species.

This species is moderately variable in the development of the median sulcus which varies from deep, narrow, and direct, to scarcely visible. Generally it

is moderately well developed, but in some specimens it is wider anteriorly than in others. The ears are also variable ranging from nearly a right angle to 65°. In some specimens the extremities are drawn into small points and the sides are nearly straight. In others the points are lacking but usually they are present. The young are usually fairly strongly transverse.

The beds from which these specimens were taken are regarded as enclosing a death assemblage, because the vast majority of the specimens are separated valves. A complete shell is a rarity.

*Dyoros (Tetragonetes) rectangulatus*, new species

PLATE 490: FIGURES 37–66; PLATE 495: FIGURES 9–12

Medium size for genus, wider than long, hinge width about 1.5 times shell length; hinge about equal to midwidth or extended slightly into small ears. Cardinal extremities approximately right angle. Sides nearly straight to slightly rounded and slightly indented just anterior to cardinal extremity. Anterior margin truncated to slightly emarginate. Anterior commissure with fairly strong dorsal fold. Posterior margin with eight oblique spines per side.

Pedicle valve gently and unevenly convex in

lateral profile, maximum convexity in anterior half; anterior profile a broad, shallow dome with short sides. Umbonal region flattened; midregion gently inflated. Sulcus broad and shallow, originating about one-quarter length from beak. Flanks bounding sulcus moderately inflated with long, gentle posterolateral slopes but steep anterolateral slopes. Interarea short, apsacline.

Brachial valve flatly concave, deepest in umbonal region and on flanks of fold. Posterolateral extremities flattened and demarcated by low, oblique fold forming dorsal flexure in lateral commissure. Fold low, broad, originating at midvalve. Interarea short, hypercline.

Pedicle valve interior with wide delthyrium and small teeth; apical callosity thick; septum short, continued anteriorly as low, fairly thick, ridge. Interior papillose.

Brachial valve interior with low and spreading, deeply excavated cardinal process; prosocket ridges short. Adductor dividing ridges short, not much extended anterior to well elevated and exposed anderidium. Brevisseptum strongly elevated anteriorly and spinose on distal half, not thickened posteriorly and only faintly extended to antron. Anterolateral side of visceral disc moderately thickened and moderately spinose.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702b							
152039a	10.3	9.6	12.5	15.2	15.4	4.0	2.9
(holotype)							
152039b	9.6	8.7	11.0	15.4	15.1	3.2	2.5
152039c	8.3	7.7	9.5	13.2	12.8*	2.5	1.8
152039d	7.7	7.4	9.0	10.6*	12.2	2.0	1.6
152039e	10.4	?	12.5	17.4	16.5	?	?
USNM 702-low							
152041	9.6	9.0	11.5	16.9	14.8	4.2	2.6

STRATIGRAPHIC OCCURRENCE.—Bone Spring, Cathedral Mountain, and Road Canyon formations.

LOCALITIES.—Bone Spring: AMNH 369. Cathedral Mountain: AMNH 500G. USNM 702, 702a, 702b, 702 low, 702un, 703a<sup>1</sup>. Road Canyon: USNM 702c, 703a, 703c, 716x, 720d.

DIAGNOSIS.—Stout-shelled, rectangular *Dyoros* (*Tetragonetes*) with broad, anteriorly developed sulcus, and broad, low fold.

TYPES.—Holotype: USNM 152039a. Figured paratypes: USNM 152039e-g; 152043; 153716; 153717; 153718a, b. Measured paratypes: USNM 152039b-e, 152041. Unfigured paratypes: USNM 152039b-d.

COMPARISONS.—This species is fairly widely rectangular and therefore not directly comparable to the more quadrate species such as *D. (T.) complanatus*, new species. It is distinguished from *D. (T.)*

*solidus*, new species, by its greater width, less deep brachial valve, and the lesser development of the sulcus as well as less convexity of the pedicle valve. It is distinguished from *D. (Lissosia) planus*, new species, by its lesser convexity of the pedicle valve, better developed sulcus, and deeper concavity of the brachial valve. Its outline is not unlike that of *D. (T.) strigosus*, new species, but that species is much flatter and laterally more angular. *Dyoros (Tetragonetes) rectangulatus* is more convex than *D. (D.) tenuis*, new species, but is much less extended along the hinge.

DISCUSSION.—This species is variable in outline but it generally maintains its widely rectangular form. It is also variable in the development of the fold and sulcus. In some, these are located chiefly on the anterior half; in others, the sulcus runs back farther toward the beak. None of the specimens are as deeply sulcate as characteristic for *Dyoros (Dyoros)*. Nor is the interior generally developed in accordance with the demands of that genus.

The median ridge of the pedicle valve extends to beyond midvalve, but is always a very low ridge. The separate posterior portion is very reduced, but in some specimens is the most elevated part of the structure. Inside the brachial valve the brevisseptum is low but rises anteriorly to a low crest. It

terminates at the head of a shallow gully formed by the slightly swollen anterolateral parts of the valve.

This species is not common at any locality, but more specimens were taken from USNM 702b, chiefly because a very large quantity of rock from that place was processed.

*Dyoros (Tetragonetes) solidus*, new species

PLATE 491: FIGURES 1-19

Medium size for genus, wider than long, hinge forming widest part; cardinal extremities angular, angle varying from 70° to 105°; sides slightly oblique to slightly rounded, usually indented slightly anterior to small ears. Anterior margin narrowly emarginate; anterior commissure with narrow dorsal fold. Posterior margin with about 8 short, oblique spines. Interarea short, procline. Pseudodeltidium not seen.

Pedicle valve fairly strongly and evenly convex in lateral profile, maximum convexity near midvalve; anterior profile broadly domed with steep sides sloping to margins, but ears not visible and strongly indented medially. Umbonal region moderately swollen; median region broadly swollen. Sulcus narrow, moderately deep, originating on

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 703d							
152015a	14.0	12.3	19.5	18.7	17.9	6.4	4.3
(holotype)							
152015b	13.6	11.5	19.0	17.8	17.9	5.7	4.6
152015c	12.6	10.9	18.5	16.6	15.0	5.6	3.9
152015d	11.4	10.2	14.0	14.2	14.0	4.5	2.8
152015e	10.3	9.6	12.5	14.9	13.4	4.0	2.4
152015f	9.4	8.0	12.0	10.8	11.4	3.8	2.8
152015g	8.2	7.6	10.0	11.9	11.0	2.7	2.0
152015h	7.4	6.7	9.0	10.7	9.8	2.3	1.6
152015i	5.8	5.3	6.5	9.0	8.2	1.8	1.2
152015j	4.9	4.6	5.5	8.2	7.2	1.5	1.0
152015k	6.3	5.9	7.5	10.4	8.8	2.6	1.3
152015l	8.8	7.7	12.0	14.9	12.7	3.8	2.6
152015m	10.1	9.1	13.0	14.0	14.7	3.9	2.5
152015n	10.9	9.4	14.0	16.4	15.1	4.1	3.2
152015o	11.0	9.7	14.0	16.8*	15.3	4.3	2.5
152015p	12.3	10.8	16.5	18.6	17.8	5.2	3.2
152015q	12.2	11.0	15.0	18.2	17.4	4.4	2.5
152015r	13.4	11.4	17.5	16.8	17.1	5.5	4.9

umbo, deepening gradually to anterior margin. Flanks bounding sulcus somewhat narrowly rounded. Lateral slopes in posterolateral region short, defining slightly convex posterolateral extremities; posterolateral slopes anteriorly becoming steep and precipitous.

Brachial valve gently concave, most concave part just anterior to umbo. Fold originating about one-third valve length from beak, narrow but elevating and widening anteriorly; flanks bounding sulcus forming deep troughs bounded laterally by oblique folds demarcating slightly concave ears. Interarea short and hypercline.

Pedicle valve interior with thick apical callosity and short but elevated septum extended into ridge, elevated onto inner fold produced by external sulcus; muscle field flabellate, strongly impressed with some longitudinal ridges and occasional elongated taleolae. Lateral regions inside margins strongly granulose.

Brachial valve interior with broad, deeply excavated cardinal process; prosocket ridges short; adductor dividing ridges well formed posteriorly but extended anteriorly nearly to anterior end of visceral region by one or more rows of taleolae. Anderidium fairly prominent and protruding. Brevisseptum usually terminating in cluster of spine-like taleolae. Anterolateral margins of visceral region thickened and strongly fringed with taleolae.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—AMNH: 503; USNM 703, 703a, 703c, 703d; 721x; 726e.

DIAGNOSIS.—*Dyoros* (*Tetragonetes*) with strong narrow sulcus in pedicle valve and nearly parallel sides.

TYPES.—Holotype: USNM 152015a. Figured paratypes: USNM 152015g–m, p; 153719a–c; 153720. Measured paratypes: USNM 152015b–r. Unfigured paratypes: USNM 152015b–f, n, o, q, r.

COMPARISON.—In young stages this species is fairly transverse but becomes more nearly square with age. It differs from *D. (T.) quadrangulatus*, new species, in having a generally shallower sulcus, less prominent ears, and lower, less prominent fold. *Dyoros* (*Tetragonetes*) *planus*, new species, is wider, thinner-shelled, much compressed, and has a much smaller development of the fold and sulcus. The same is true of *D. (T.) complanatus*, new species, which is also greatly compressed and has a

very short, shallow sulcus. *Dyoros* (*Tetragonetes*) *lateralis* and *rectangulatus*, both new species, are wider and have more prominent ears than *D. (T.) solidus* and the former is a much larger shell.

DISCUSSION.—This is a variable species, the young tending to be fairly strongly transverse, the adults becoming more nearly square but never attaining equal length and width. The species does not conform to Stehli's definition of *Dyoros*, which calls for "strongly transverse" dimensions. The interiors of both valves however conform well to the definition. The brachial valve interiors generally show strongly thickened and well-fringed anterolateral margins of the visceral region.

Many specimens have well-defined and sharply angular but small points on the cardinal extremities; others approach a right angle. The young usually have fairly strongly pointed cardinal extremities. The brachial valves are variable in their concavity, the specimens of median age usually are more concave, but none of them are very deep. This species is fairly common at USNM 703d; the collection includes many specimens with both valves in contact, as well as single valves.

### *Dyoros* (*Tetragonetes*) *strigosus*, new species

PLATE 491: FIGURES 33–42

Large for genus, subrectangular in outline, hinge forming the widest part. Cardinal extremities extended into small points; sides oblique and anterior margin slightly indented medially. Anterior commissure with light fold toward dorsal valve. Posterior margin with 8 oblique spines on each side.

Brachial valve in lateral profile slightly convex, maximum convexity in posterior third. Anterior profile a broad, low dome with long, gently sloping sides. Umbonal region slightly swollen; median region slightly swollen and with long gentle slopes to posterolateral extremities. Sulcus originating just anterior to umbo, shallow and broadening anteriorly but shallow throughout. Flanks bounding sulcus broad and slightly inflated. Interarea short, apsacline.

Brachial valve nearly flat but with slight concavity in umbonal region. Fold originating just anterior to umbonal pit broadly subcarinate and moderately elevated. Flanks bounding fold forming shallow troughs to anterolateral extremities.

Posterolateral extremities flattened and demarcated by low ridge bounding troughs flanking fold. Interarea short, hypercline.

Pedicle valve with small teeth, strong apical callosity and short median septum. Ridge anterior to septum moderately strong and extending beyond midvalve.

Brachial valve interior not known.

MEASUREMENTS (in mm).—From locality USNM 703d specimens 152036a (holotype) and b, respectively: length 10.8, 9.1; brachial valve length 10.1, 8.4; surface length 11.0, 10.0; hinge width 18.4, 16.7; midwidth 17.2, 14.0; height 2.3, 2.5; thickness 1.1, 1.4.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITY.—USNM 703d.

DIAGNOSIS.—Nearly flat and thin-shelled *Dyoros* (*Tetragonetes*).

TYPES.—Holotype: USNM 152036a. Figured and measured paratype: USNM 152036b.

COMPARISONS.—This species can be recognized and distinguished from all other species by the extremely low convexity of the pedicle valve and the relatively wide shell that yet preserves the quadrangular outline of the subgenus.

DISCUSSION.—Few specimens of this species have been found, consequently the variation and some details cannot be recorded.

*Dyoros* (*Tetragonetes*) *subquadratus*, new species

PLATE 490: FIGURES 67–77; PLATE 491: FIGURES 20–32; PLATE 498: FIGURES 33–37

Fairly large for genus, subquadrate in outline, width greater than length, hinge widest part. Car-

dinal extremities narrowly rounded. Sides slightly oblique to nearly straight, with small concavity anterior to posterolateral extremities. Lateral commissure with dorsal fold just anterior to midvalve. Anterior margin nearly straight, deep median indentation. Anterior commissure with strong dorsal fold. Posterior margin with six to eight oblique spines on each side.

Pedicle valve moderately and fairly evenly convex in lateral profile, maximum convexity at midvalve. Anterior profile forming broad dome widely and deeply depressed medially and with short moderately steep sides. Umbonal region swollen; median region moderately swollen. Sulcus originating at umbo, fairly wide and deep, and indenting anterior margin. Flanks forming narrowly rounded folds with short but steep sides. Posterolateral extremities strongly depressed. Interarea long, orthocline to anacline.

Brachial valve moderately concave, deepest part divided by fold to form two moderately deep troughs. Fold originating just anterior to umbo, narrowly rounded at origin, but widening and elevating anteriorly to form broad dorsal flexure of commissure. Posterolateral extremities flattened and defined by strong, oblique folds meeting side near midvalve.

Pedicle valve interior with thick apical callosity, short but high median septum with fairly strong ridge extending anteriorly beyond midvalve. Teeth narrow but thick and with deep fossettes. Interior surfaces strongly granulose.

Brachial valve interior with small excavated cardinal process having antron completely filled in some specimens. Prosocket ridges short but strong. Adductor dividing ridges strong and slender, anteridium protrudent; brevisseptum strong, highest

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 728							
151988a	14.7	12.7	19.0	21.0	19.8	5.5	3.9
(holotype)							
151988b	14.8	12.8	18.0	19.8	18.7	5.2	3.8
151988c	13.5	11.6	18.0	17.8	17.7	5.9	4.2
151988d	12.2	10.6	15.0	17.9	16.5	5.4	3.4
151988e	11.8	10.0	15.0	17.8	16.1	4.4	3.0
151988f	9.2	8.2	12.0	13.3	12.6	3.7	2.9
151988g	7.5	6.8	9.0	11.0	10.6	2.9	2.0



anteriorly, there spinose and extending to antron and united with adductor dividing plates by callus. Visceral region thickened on lateral and anterolateral margins and strongly spinose anteriorly.

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member).

LOCALITY.—AMNH 512=USNM 728.

DIAGNOSIS.—Thick-shelled moderately transverse *Dyoros* (*Tetragonetes*) with wide, strong fold and sulcus and narrowly rounded cardinal extremities.

TYPES.—Holotype: USNM 151988a. Figured paratypes: USNM 151988b, d, h–k. Measured paratypes: USNM 151988b–g. Unfigured paratypes: USNM 151988c, e–g.

COMPARISONS.—This is a large species occurring with *D. (D.) convexus*, new species, from which it differs in its definitely quadrangular outline, lesser convexity, wider sulcus, less extended and more rounded ears. In these respects it differs also from *D. (D.) extensus*, new species. *Dyoros (D.) planiextensus*, new species, has sharper cardinal extremities but also a flatter brachial valve.

The exterior form of *D. (T.) subquadratus* suggests *D. (T.) solidus*, which is a smaller species, with less concave brachial valve, and with a much lesser development of the fold and sulcus.

DISCUSSION.—The interior details of this species are strongly marked because of the thickness of the shells. Nevertheless, the swelling and spinosity of the anterolateral part of the visceral region is not very strongly marked or excessive except in extremely old specimens.

### *Dyoros (Tetragonetes) tetragonus*, new name

PLATE 499: FIGURES 66–68, 69?

*Chonetes quadratus* R. E. King [not Trenker, 1867; not Girty, 1929], 1931:63, pl. 9: figs. 8?, 9, 10? [not figs. 7, 11 (= *D. (Tetragonetes) quadrangulatus*, new species).]

King (1931) based this species on specimens from the Glass Mountains and the Grand Canyon. The type lot consists of five specimens, two from the Grand Canyon and three from the Glass Mountains. King selected one of the Grand Canyon specimens (YPM 10830, pl. 9: fig. 9) as holotype. King's type proves to be different from the Glass Mountains specimens. We propose to replace King's preoccupied name with the species designation *tetragonus* in allusion to its squarish outline.

The holotype is rectangular, with the midwidth slightly greater than the length and with the hinge slightly less than the midwidth. The sides are slightly convex and the anterior margin truncated but medially slightly indented. The lateral profile is fairly strongly convex and the anterior profile is a narrow, steep-sided dome medially indented. The umbo is low and the sulcus originates just anterior to it. The sulcus is narrow and shallow, widening only slightly anteriorly. Flanks bounding the sulcus are moderately and broadly swollen and have short slopes to the cardinal extremities. The posterolateral region is moderately depressed and approximates a right angle with no development of ears or auriculations. Brachial valve not visible.

MEASUREMENTS (in mm).—Holotype YPM 10830a: length 12.4, surface length 16.0, hinge width 14.8, midwidth 15.5, height 4.6.

DISCUSSION.—The paratype (YPM 10830b) differs from the holotype in the great strength of its sulcus which is wide and deep and bounded by narrowly rounded plications. The outline, margins, and cardinal extremities are like those of the holotype. Without intermediates it is impossible to regard these two specimens as belonging to the same species.

No species in the Glass Mountains can be identified with the type of *D. (Tetragonetes) tetragonus*. Specimens from the Appel Ranch Member of the Word Formation have the squarish outline, but have a subdued sulcus and prominent ears.

In his description of the Kaibab Limestone of the Grand Canyon, McKee (1938:227) placed King's *C. quadratus* in the synonymy of his new species *C. kaibabensis*, a taxonomically illegal procedure. McKee's species seems to us quite unlike King's.

### *Dyoros (Tetragonetes) wordensis*, new species

PLATE 490: FIGURES 20–36

Medium size for genus, narrowly trapezoidal in outline, hinge widest, sides sloping medially, anterior margin somewhat narrowly rounded and indented slightly medially; cardinal extremities forming large acute angle, almost 70° to 75°. Anterior commissure with narrow dorsal fold; posterior margin with about 8 short oblique spines on each side.

Pedicle valve with gently convex lateral profile, but anterior profile broad dome medially and narrowly depressed, with moderately sloping sides; umbonal and median regions swollen, sulcus originating on umbo, extending to anterior margin, narrow and deep at anterior. Flanks forming narrowly rounded folds; ears angular, not strongly depressed. Interarea curved, orthocline to apsacline.

Brachial valve moderately concave, most depressed medially; oblique depressed areas corresponding to ventral folds deep and marked off from flattened ears by strong flexure. Fold originating

near midvalve, subangular and fairly strong at anterior margin.

Pedicle valve interior with moderate callus in apex; median septum low but emphasized by ridge formed by exterior sulcus; septum marked by short spines on crest; diductor scars very large; remaining surface granulose.

Brachial valve interior with thick cardinal process having deep antron; median ridge anteriorly thickened and spinose; areas lateral to median ridge strongly endospinose. Adductor dividing ridges low; anderidia not strongly developed.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706e							
152026a	11.6	10.6	14.0	19.0	16.2	4.1	2.6
152026b	12.3	11.5	16.0	16.5	16.3	4.2	3.4
152026c	10.3	9.5	12.5	16.6	15.4	3.6	2.4
(holotype)							
152026d	11.3	10.0	14.0	14.3?	15.9	3.3	2.7
152026e	10.5	9.9	12.0	15.8?	14.1	3.0	2.2
152026f	8.9	8.0	10.5	12.3	12.2	2.3	1.5
152026g	10.5	9.5	13.0	15.8	14.7	3.8	2.9
152026h	9.6	8.8	11.5	12.0?	13.1	3.0	1.7
152026i	8.7	8.6	11.5	?	13.0	4.2	2.9
152026j	7.1	6.2	8.0	10.4	9.6	2.1	1.6

STRATIGRAPHIC OCCURRENCE.—Word Formation (Willis Ranch Member and lens between Willis Ranch and Appel Ranch members).

LOCALITIES.—USNM 706, 706e, 723t. Lens:706b.

DIAGNOSIS.—Medium *Dyoros* (*Tetragonetes*) having a strong fold and sulcus.

TYPES.—Holotype: USNM 152026c. Figured paratypes: USNM 152026e, g, l–n. Measured paratypes: USNM 152026a, b, d–j. Unfigured paratypes: USNM 152026a, b, d, f, h–k, o.

COMPARISON.—*D. (Tetragonetes) wordensis* is very distinctive, suggesting *D. (D.) consanguineus* (Girty) in its strong narrow sulcus but differing in its narrower outline more referable to *Tetragonetes*. It is thicker, with a stronger fold and sulcus than that of *D. (Tetragonetes) complanatus*, new species; thinner and somewhat wider than *D. (T.) quadrangulatus*, new species; and more angular, deeper and more sulcate than *D. (T.) rectangularis*, new species. Its form is like that of *D. (T.)*

*subquadratus*, new species, but it is less deep, less robust, and has more acute ears and more sloping sides. This species is rare in the Willis Ranch Member, and still rarer in the lens between the Willis Ranch and Appel Ranch members (USNM 706b).

#### Genus *Lissochonetes* Dunbar and Condra, 1932

*Lissochonetes* Dunbar and Condra, 1932:169—Stehli, 1954:310—Muir-Wood, 1962:76—Williams et al., 1965:H430.

Medium sized chonetids, generally transversely rectangular in outline with the hinge usually forming the widest part; cardinal extremities variable, acute to slightly obtuse; anterior commissure broadly rounded to truncated. Anterior commissure with broad dorsal fold. Sulcus poorly and usually only anteriorly defined. Posterior spines oblique.

Pedicle valve interior with small apical callosity

and short, poorly defined median septum. Ridge anterior to septum low and reaching about to mid-valve. Diductor scars flabellate, poorly impressed. Granules strong, arranged in radial rows.

Brachial valve interior with small excavated cardinal process; prosocket ridges short, oblique; adductor dividing ridges slender; anderidia slender and elevated. Brevisseptum reaching to slightly beyond midvalve, slender and delicate. Granulation fine and granules arranged in rows.

TYPE-SPECIES.—*Chonetes geinitzianus* Waagen, 1884:621 (= *Chonetes glabra*) Geinitz (not Hall), 1866:60, pl. 4:figs. 15–18.

DIAGNOSIS.—Thin-shelled, depressed, medium-sized Chonetacea having delicately developed interior details.

COMPARISONS.—A genus as poorly defined and little understood as *Lissochonetes* is difficult to compare with other genera. Of other smooth genera, those most likely to cause confusion are *Dyoros* (*Dyoros*) Stehli and its subgenera, *Leurosina*, new genus, and *Undulella* Cooper and Grant, and its subgenus *Lissosia* are usually easy to distinguish from *Lissochonetes* because they are generally strongly transverse, alate and deeply sulcate on the ventral side of *Dyoros* (*Dyoros*) and deep, but not strongly sulcate, on the ventral side of *Lissosia*. These are features that Stehli (1954) emphasized when he defined *Dyoros*. In addition, the strongly spiny and swollen anterolateral part of the inner visceral region of *Dyoros* (*Dyoros*) is another ready means of distinction.

*Leurosina* and *Lissochonetes* may be confused in poorly preserved specimens, but in good material they are readily distinguishable on the basis of both exterior and interior. The folding of *Leurosina* is very broad and usually affects only the anterior margin. Details of the brachial valve interior of *Leurosina* are generally more thickened and positive than those of *Lissochonetes*.

*Undulella* externally suggests *Lissochonetes* but its brachial valve is thickened in different parts than that of the latter. Furthermore the posterior marginal spines of *Undulella* extend nearly at right angles to the posterior margin whereas those of *Lissochonetes* are oblique.

*Lissochonetes* is constructed so differently from typical *Chonetina* Krotov, *Chonetinetes* Cooper and Grant, and *Tornquistia* Paeckelmann that no confusion between them should exist.

DISCUSSION.—*Lissochonetes* as identified by us, by Dunbar and Condra, and others, appears to be a variable genus. This is probably due to the uncertainty and indefinite characters of the species selected as type. Specimens of *L. geinitzianus* (Waagen) from the type locality occur in a soft shale and suggest specimens that lived in an environment not entirely hospitable, resulting in only modest calcification of the shell. Dunbar and Condra's *L. geinitzianus* var. *geronticus* strongly deviates from the type in the sulcus and fold, in the thick calcification of the interior, and in the development of a median trough in the brachial valve just anterior to the end of the brevisseptum. It is placed in *Quadrochonetes* by Muir-Wood (1962:84). We have been able to identify only one of our species with *Lissochonetes*.

### *Lissochonetes parvisulcatus*, new species

PLATE 491: FIGURES 43–45

Small for genus, transversely rectangular in outline, widest at hinge; cardinal extremities drawn into acutely pointed ears. Sides indented anterior to ears but nearly straight or slightly oblique anteriorly; anterior margin truncated to broadly rounded. Anterior commissure with broad dorsal fold. Posterior margin with five oblique spines on each side of beak.

Pedicle valve gently convex in lateral profile and forming broad, low dome with moderately sloping sides in anterior profile. Umbo barely perceptible; median region slightly inflated. Sulcus originating at or near midvalve, usually defined best at anterior half; sulcus usually wide and shallow, commonly appearing as low ventral fold of anterior half.

Brachial valve moderately concave and most so in posteromedial region; fold fairly strong, broadly rounded and best defined at anterior, there flanked by moderately deep troughs. Ears not strongly demarcated.

Interior of both valves not known.

MEASUREMENTS (in mm).—From locality USNM 701p, specimens 151993a (holotype) and c, respectively: length 5.7, 5.6; brachial valve length 5.4, 5.0; surface length 6.5, 6.5; hinge width 9.2\*, 9.6; midwidth 8.8, 8.9; height 1.6, 1.6; thickness 0.6, 0.5.

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member).

LOCALITY.—USNM 701p.

DIAGNOSIS.—Small *Lissochonetes* with sulcus confined to anterior half.

TYPES.—Holotype: USNM 151993a. Figured and measured paratype: USNM 151993c. Unfigured paratypes: USNM 151993b, d–f.

COMPARISONS.—This is the smallest of the species of *Lissochonetes* and suggests a small, more narrowly sulcate edition of *L. geronticus* Dunbar and Condra. It is not as extended along the hinge as that species and its sulcus is not so deeply impressed. It is distinguished from the young of other species by its strong sulcus, a feature usually not well developed in the young of larger species that have attained the size of *L. parvisulcatus*. This is a rare species from the upper part of the shales of the *Uddenites*-bearing Shale Member of the Gaptank Formation.

### *Leurosina*, new genus

[Greek *leuros* (smooth)]

Small to medium-sized shells, usually transversely rectangular in outline, hinge generally nearly equal to midwidth. Ears small or not developed. Pedicle valve fairly strongly convex and brachial valve nearly flat to gently concave. Anterior commissure varying from unfolded to broadly deflected in dorsal direction, deflection broadly affecting anterior margin. Surface smooth and posterior margin with oblique spines.

Pedicle interior with narrow delthyrium, small teeth and short rimlike pseudodeltidium; interarea short. Median septum short and thick apically but extended anteriorly to beyond midvalve as narrow, moderately elevated ridge. Muscle field widely flabellate.

Brachial valve with deeply excavated cardinal process and short oblique prosocket ridges. Adductor dividing ridges and anteridia fairly well developed. Brevisseptum long, low, extending from beyond midvalve to antron. Visceral region slightly thickened anterolaterally and laterally but granulate to moderately spinose.

TYPE-SPECIES.—*Leurosina marginata*, new species.

DIAGNOSIS.—Smooth, widely rectangular Chonetacea having the anterior commissure unfolded or broadly deflected.

COMPARISON.—This genus is most like *Lissochonetes* and *Eolissochonetes* Hoare in the general form of the valves but its cardinal extremities are seldom drawn into sharp points, it has thicker shells, and the anterior is broadly deflected in a dorsal direction rather than being sulcate. On the inside, the septa of both valves are better and more strongly developed than in either of the other genera. Furthermore the visceral region of the brachial valve is fairly strongly thickened and strongly granulose.

The genus differs from *Dyoros* (*Dyoros*) Stehli in not having the pronounced and usually fairly narrow median sulcus in the pedicle valve and strong fold in the brachial valve. The visceral region is less strongly fringed than in that genus. It differs from *Dyoros* (*Lissosia*), new subgenus, in its narrow hinge and bulging sides.

*Quadrochonetes*, with its wide sulcus and subangular bounding plications is entirely unlike *Leurosina*. *Undulella* resembles *Leurosina* in its broadly deflected anterior but differs in the pattern of the brachial interior.

DISCUSSION.—The exterior form of *Leurosina* is fairly distinctive. The broad deflection of the anterior of both valves produces a slightly convex to truncated anterior margin. But in some specimens, especially old ones, an indistinct and narrow fold forms on the anterior part of the pedicle valve, producing a small tongue at the anterior margin, so that a distinctly lobate form is produced. On the opposite valve a corresponding slight sulcus is produced to form a small fold at the anteromedian extremity, just anterior to the brevisseptum.

Inside the pedicle valve of *L. marginata* and *L. lata*, both new species, the lateral and anterior borders are depressed, flattened, and finely granulate to produce a conspicuous border around the visceral region. In the brachial valve a similar finely granulate border forms a flattened rim on the sides and anterior of the visceral region.

The two new species of the Word Formation have conspicuously thickened brachial valve interiors. In *L. marginata* the thickening is mostly along the anterolateral sides of the visceral region, giving this valve the appearance of *Dyoros* (*Dyoros*) except that the thickening and granulation are not strong as in typical members of that genus. In *L. lata* thickening of the interior takes place inside the anterior and lateral parts of the visceral region. This thick-

ening extends from the anterior end of the adductor scars in a curve concave anteriorly inside the loops of the visceral region. When well preserved, the brevisseptum is strongly elevated, most so anteriorly, where its long sloping extremity is serrated or spinose.

*Leurosina delicata*, new species

PLATE 494: FIGURES 1-14

Usual size for genus, wider than long, rectangular in outline. Hinge usually narrower than midwidth but in some specimens aberrantly drawn into small points; cardinal extremities varying from slightly acute to slightly obtuse. Sides nearly straight to gently rounded. Anterior margin broadly rounded to subtruncate. Anterior commissure with broad dorsal fold. Posterior margin with 8 or 9 short oblique spines.

Pedicle valve with gently convex lateral profile,

most convex near midvalve; anterior profile broadly convex, top flattened, sides moderately steep. Umbonal region small; median region moderately inflated, with moderately steep slopes to cardinal extremities but with steeper anterior slope. Ears not defined. Interarea short, apsacline.

Brachial valve nearly flat to gently concave, posterolateral extremities flat but median region slightly concave. Anterior quarter sharply deflected in dorsal direction to form broad fold.

Pedicle valve interior with small and narrow delthyrium and small teeth; apical callosity small; median septum not developed. Median ridge low and delicate, extending to beyond midvalve. Granules small and delicate.

Brachial valve interior with small, delicate, excavated cardinal process. Prosocket ridges small, oblique. Adductor dividing ridges small, andridium delicate. Brevisseptum delicate, extending to beyond midvalve. Visceral region slightly thickened and with delicate granulation.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 728							
152132a	12.2	?	14.5	17.2	18.8	3.7	?
152132b	11.3	?	14.0	17.2	18.4	3.8	?
152132c	10.7	?	13.0	13.2	16.0	3.1	?
152132d	9.1	?	10.5	12.8	14.1	2.5	?
152132e	9.5	8.6	11.0	12.0	12.7	2.8	2.2
(holotype)							
152132f	8.2	7.7	9.5	12.8	13.0	2.3	1.9

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member).

LOCALITIES.—AMNH 512 (= USNM 728), 600.

DIAGNOSIS.—*Leurosina* with delicately granulose and only slightly thickened interior.

TYPES.—Holotype: USNM 152132e. Figured paratypes: USNM 152132a, f–h. Measured paratypes: USNM 152132a–d, f. Unfigured paratypes: USNM 152132c, d.

COMPARISONS.—This species differs from *L. lata* and *L. marginata*, both new species, in the very slight thickening of the interior and the delicate granulation. This is an uncommon species in the Guadalupe Mountains, but its distinctive form makes identification fairly easy.

*Leurosina lata*, new species

PLATE 479: FIGURES 68-78; PLATE 494: FIGURES 15-44

Usual size for genus, transversely rectangular to broadly elliptical in outline but variable; hinge aberrantly wider than, equal to or less than midwidth but usually slightly less; sides nearly straight to gently rounded; anterior broadly rounded to somewhat linguiform and thus broadly trilobate. Anterior commissure with broad dorsal fold. Posterior margin with 10 oblique spines on each side of the beak. Pseudodeltidium short and narrowly convex.

Pedicle valve moderately convex in lateral pro-



file, maximum convexity near midvalve but anterior third somewhat flattened. Anterior profile broadly domed and with long sloping sides. Umbonal and median regions moderately swollen with moderate slopes to cardinal extremities but steep anterior slope. Sulcus originating at midvalve, broad and shallow and bounded laterally by indistinct slightly swollen folds; sulcus in some specimens marked medially by low, narrow fold. Posterolateral extremities somewhat flattened. Interarea short, orthocline to apsacline.

Brachial valve gently concave, concavity forming transverse trough bounded by flattened lateral extremities and dorsally folded anterior half; fold in some specimens with shallow median sulcus cor-

responding to fold in sulcus of opposite valve. Interarea short, hypercline.

Pedicle valve interior with thick apical callosity and short stout median septum, extended anteriorly as moderately elevated ridge. Interior finely papillose.

Brachial valve interior with low cardinal process, antron partly to nearly completely filled; prosocket ridges short; adductor dividing ridges variably developed, commonly greatly thickened and spinose; anderidia easily seen in young specimens but commonly buried in obese shells. Lateral and anterior margins of visceral disc greatly thickened, bounding swollen inner region in many specimens. Breviseptum moderately developed.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706c							
152138a	12.4	10.9	15.0	22.0*	21.5	4.7	3.2
(holotype)							
152138b	10.2	8.7	12.0	18.0*	17.0	3.6	2.3
152138c	10.3	9.4	12.0	18.0*	17.0	3.4	2.1
USNM 706b							
152136a	11.6	10.3	14.5	19.8	19.1	4.2	2.7
USNM 706							
152134a	12.4	?	15.5	22.0	20.8	4.2	?
152134b	11.4	?	13.5	20.3	18.8	3.6	?
152134c	11.0	?	13.5	18.2	17.8	4.2	?
152134d	10.7	?	13.5	18.4	18.0	3.8	?
USNM 732j							
153682a	11.7	10.4	15.0	18.0	19.0	4.6	3.3
USNM 706e							
152140a	10.3	9.5	12.5	18.0	17.6	3.7	2.6
152140b	12.0	?	15.5	17.8	18.8	4.6	?
152140c	12.0	?	14.5	20.0	19.6	4.4	?
152140d	11.8	?	14.5	17.3	18.0	3.7	?
152140e	11.0	?	13.5	17.0	17.5	3.8	?
152140f	9.6	8.6	11.5	14.6	15.8	3.4	2.4
152140g	8.7	7.6	10.0	13.3	13.2	3.0	2.3

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation, Word Formation (China Tank, Willis Ranch, Appel Ranch members and the lower lens between the two).

LOCALITIES.—Road Canyon: USNM 721j, 732j, 736x. China Tank: USNM 706c, 726r. Willis Ranch: USNM 706, 706e, 723t, 724u. Appel Ranch: USNM 715i, 737b. Lens: USNM 706b.

TYPES.—Holotype: USNM 152138a. Figured

paratypes: USNM 152136a–c; 152138e, f; 152140a, h–k; 153728c. Measured paratypes: USNM 152134a–d; 152136a; 152138b, c; 152140a–g; 153682a. Unfigured paratypes: USNM 152134a–d; 152138b, e, d; 152140a–g.

COMPARISONS.—This species differs from *L. marginata*, new species, in being proportionately wider, in having definite points on the cardinal extremities, the anterior margin generally more lobate

medially, and the brachial valve more strongly thickened, especially the parts just anterior to the adductor field. Furthermore, the granulation of the interior of the visceral region is stronger than that of *L. marginata*.

*Leurosina delicata*, new species, from the Guadalupe Mountains, has delicately developed interior details in both valves and is proportionately less wide than *L. lata*.

DISCUSSION.—This species occurs in the Road Canyon Formation and in the fossiliferous limestones of the Word Formation. Specimens from the lowest of the Word limestones appear to have a somewhat greater width than those from higher beds. Specimens from the lower part of the Willis Ranch Member are quite delicate and not strongly thickened. Furthermore they are not common. Specimens from the upper part of the Willis Ranch Member are well thickened and typical of the species. Those from the lens between the Willis Ranch and Appel Ranch members are rare, and are strongly thickened in both valves, more so than those from the upper part of the Willis Ranch.

This species is very rare in the Road Canyon Formation, from which only a few good specimens were taken. Those from USNM 732j have the same measurements as specimens from the higher Word limestones but their interior details are more strongly impressed than usual. A few specimens from the Road Canyon Formation are clearly a different species but we have only pedicle valves. These show a narrower and deeper species.

*Leurosina marginata*, new species

PLATE 495: FIGURES 13-34

Transversely rectangular to broadly elliptical in outline; hinge equal to or slightly less than midwidth; cardinal extremities nearly right angle or slightly obtuse. Minute ears occasionally present. Sides nearly straight to gently rounded. Anterior margin broadly rounded and produced into broad tongue in some specimens. Anterior commissure with broad dorsal fold. Posterior margin with 8 short, oblique spines on each side; interarea moderately long, orthocline. Pseudodeltidium narrowly convex.

Pedicle valve moderately but unevenly convex in lateral profile, maximum convexity near midvalve, but anterior quarter or third depressed in dorsal direction. Anterior profile broadly and moderately convex. Umbonal region moderately swollen; mid-region fairly strongly swollen and with long slopes to cardinal extremities, but anterior slope steep. Sulcus defined as broad, shallow, flattening or depression in anterior quarter to half. Flanks bounding sulcus slightly swollen. Cardinal extremities flattened.

Brachial valve shallow, deepest near midvalve but anterior quarter or third bent gently in dorsal direction; flanks bounding folded region forming shallow troughs. Posterolateral extremities flattened.

Pedicle valve interior with narrow delthyrial cavity occupied by thick and short median septum extended anteriorly as ridge varying from thin and

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 715i							
152128a	12.6	11.5	16.0	17.6	19.5	4.8	3.2
152128b	13.2	11.2	16.0	17.0	19.4	4.6	3.0
(holotype)							
152128c	11.3	9.9	13.5	15.3	16.7	3.8	?
152128d	7.9	7.2	9.0	11.8*	11.9	2.4	1.8
152128e	9.7	8.9	10.5	13.6*	14.1	2.4	1.8
152128f	9.8	8.9	10.5	15.4	14.7	2.0	0.9
152128g	6.0	5.7	6.5	9.0	8.8?	1.8	1.4
152128h	4.1	3.8	4.5	6.0	6.1	1.2	1.0
152128i	3.8	3.4	4.0	5.8	5.7	1.4	?

low, to proportions of septum with crest and spines. Muscle field widely flabellate. Margins somewhat depressed to form flattened border around deep

visceral region; lateral slopes and inner lateral margins strongly papillose.

Brachial valve interior with moderately large and

deeply excavated cardinal process; prosocket ridges short. Adductor dividing ridges short but extended anterolaterally as rows of thick spines. Anderidium strongly elevated. Brevisseptum in adult strongly elevated and spiny on distal end and slope. Anterior and anterolateral margins of visceral region abruptly and strongly elevated to form thick spiny anterior margin. Lateral margins flattened and strongly papillose.

STRATIGRAPHIC OCCURRENCE.—Word Formation (Appel Ranch Member).

LOCALITIES.—USNM 715i, 719z, 722t, 727j.

DIAGNOSIS.—*Leurosina* with hinge and midwidth almost the same, the brachial valve internally moderately thickened.

TYPES.—Holotype: USNM 152128b. Figured paratypes: USNM 152128a, j–m. Measured paratypes: USNM 152128a, c–i. Unfigured paratypes: USNM 152128c–i.

COMPARISONS.—This species is proportionately narrower than *L. lata*, new species, usually has lesser development of points on the cardinal extremities, and the brachial valves are less heavily thickened and have finer granules than the interiors of *L. lata*. The proportions of *L. delicata*, new species, and *L. marginata* are almost the same, but the development of the interiors is different. The strong margins of the Glass Mountains species are not developed in *L. delicata* but the interiors of both valves of *L. delicata* contrast strongly with the positive character of the interiors of *L. marginata*.

DISCUSSION.—This is the commonest of the species of *Leurosina*. The thickening of the pedicle valve

is carried to the greatest degree in this species but the structures are variable. The median ridge, for example, varies from subdued to well elevated; in a few specimens it is elevated to a crest at the distal end, where it forms a veritable saw-edge. Variable, too, is the development of the small fold on the pedicle valve. In some specimens this produces a definite prolongation of the anterior margin, but in others it is scarcely developed.

*Leurosina serratoseptata*, new species

PLATE 495: FIGURES 35–53

Medium size for genus, subrectangular in outline, hinge equal to or slightly wider than midwidth. Cardinal extremities nearly right angled, more or less. Sides slightly rounded, nearly straight or faintly convex. Anterior margin broadly rounded. Anterior commissure with a barely perceptible dorsal fold. Posterior margin with 7 or 8 moderately long oblique spines.

Pedicle valve evenly and moderately convex with maximum convexity at midvalve; anterior profile a broad, low dome with long moderately sloping sides. Umbonal region very slightly swollen and inconspicuous. Median region inflated, with long slopes to posterolateral extremities, but steeper anterolateral and anterior slopes. Sulcus barely perceptible and usually visible on anterior slope and commissure. Posterolateral extremities not strongly demarcated. Interarea moderately long, orthocline.

Brachial valve flatly concave, with most of depression in midvalve region. Fold barely percep-

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 728d							
151999a	10.8	?	13.0	15.2	15.0	2.6	?
151999b	9.7	?	11.5	15.2	14.3	2.5	?
151999c	9.5	?	12.0	15.0	14.4	3.2	?
151999d	9.6	?	11.5	15.7	14.3	2.4	?
151999e	9.6	?	11.5	13.1	13.9	2.5	?
151999f	8.8	?	10.0	13.7	13.0	2.4	?
151999g	7.8	?	9.0	11.9	11.2	2.2	?
151999h	7.8	?	8.5	12.0	12.2	2.3	?
151999i	8.2	7.7	9.5	13.6	12.6	2.3	1.7
151999j	6.9	?	7.5	11.0	10.8	1.6	?
151999-l	11.0	9.8	14.0	15.6*	16.3	4.1	2.2
(holotype)							

tible and usually confined to anteromedian third or half. Flanks bounding fold forming shallow troughs. Posterolateral extremities not demarcated. Interarea short, hypercline.

Pedicle valve interior with small oblique teeth having deep fossettes. Apical callosity moderately thick; median septum very short. Ridge anterior to septum fairly strongly developed, usually spiny for half its length, giving zigzag appearance. Adductor field small; diductors surrounding adductor patch. Interior with numerous rows of strong pustules.

Brachial valve interior with moderate-size excavated cardinal process and narrow, oblique thick prosocket ridges defining wide and deep sockets. Adductor dividing ridges not well formed but anteridia well formed and protrudent. Brevisseptum low and much reduced, barely visible in some specimens. Entire interior with rows of coarse pustules.

STRATIGRAPHIC OCCURRENCE.—Upper Hueco Formation.

LOCALITY.—USNM 728d.

DIAGNOSIS.—Rectangular *Leurosina* with slight development of fold and sulcus and strongly serrate median ridge in the pedicle valve.

TYPES.—Holotype: USNM 151999-l. Figured paratypes: USNM 151999k, m-q. Measured paratypes: USNM 151999a-j. Unfigured paratypes: USNM 151999a-j.

COMPARISON.—This species differs from all others of this genus described herein in the slight development of the fold and sulcus and the unusual development of the median ridge. In outline and profile it suggests *Dyoros* (*Tetragonetes*) *complanatus*, new species, but is more convex and has less fold and sulcus.

DISCUSSION.—The most interesting detail of the interior is the serration of the median ridge of the pedicle valve. This is not evenly developed among the specimens, but this may be due to imperfect preservation or accidents of etching as well as to variation within the species. The septate part of the ridge just anterior to the apical callosity is fairly strong and well developed. Anterior to this, the ridge is variously developed, but commonly is strong and more elevated than usual in the genus. The anterior half or more of the ridge is usually strongly spinose, with the spines extending laterally in either direction, but usually haphazard in arrangement. The anterior marginal parts of the shell are moderately and radially granulose.

The brachial valve has the pentaseptate arrangement seen in other species of this genus but the septa in this species are not usually much thickened. Although the brevisseptum is fairly strong it is not spinose or serrate, as it commonly is in other species.

### *Leurosina sinesulca* (Stehli)

PLATE 494: FIGURES 45-65; PLATE 498: FIGURES 13-32, 44-48;  
PLATE 500: FIGURES 33-40; PLATE 663: FIGURES 13, 14 (in  
volume 5)

*Lissochonetes sinesulcus* Stehli, 1954:311, pl. 19: figs. 5-8.

This species does not conform to the essentials of *Lissochonetes* as defined herein. It is also not typical of *Leurosina*, as shown by the fairly even rounding of the pedicle valve, but it seems to be better placed here than in *Lissochonetes*. Stehli's species is fairly large and has the hinge nearly equal to or slightly greater than midwidth, and the brachial valve is moderately concave. It is not close to any other species of this genus except for *L. vulgarica*, new species, from which it differs in being considerably larger in the adult form, and in having a less deep brachial valve and a wider outline.

MEASUREMENTS (in mm).—From locality AMNH 625, a complete specimen USNM 152156a: length 10.7; brachial valve length 9.7; surface length 13.0; hinge width 15.8; midwidth 15.5; height 3.5 and thickness 2.1. Another pedicle valve measures: length 13.7; surface length 16.5; hinge width 21.4; midwidth 21.8; height 4.0.

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation.

LOCALITIES.—AMNH 625, 631; USNM 725y, 728e.

TYPES.—Lectotype: AMNH 27293/1:1. Figured paratype: AMNH 27293/1:2. Figured hypotypes: 152156a, 153729a-e, 153741a-f, 153742a-c, 153751a-c.

### *Leurosina vulgarica*, new species

PLATE 495: FIGURES 1-8

Small, transversely subrectangular in outline, hinge normally wider than midwidth, rarely slightly less; cardinal extremities forming small, blunt points in young but nearly right angle or

slightly obtuse in large specimens. Sides nearly straight and oblique to slightly concave. Anterior margin broadly rounded. Anterior commissure unfolded. Posterior margin with six spines.

Pedicle valve in lateral profile moderately and evenly convex, most convex at midvalve. Anterior profile broad dome with moderately short and steep sides. Umbonal region slightly swollen; median region inflated. No sulcus. Anterior slope moderately steep.

Brachial valve fairly strongly concave, and deepest at midvalve; lateral slopes to midvalve moderately steep, but anterior slope gentle. Posterolateral

extremities flattened and demarcated by low, oblique fold meeting lateral margin near midvalve.

Pedicle valve interior with thick, oblique teeth and strong apical callosity. Median septum short and stout. Ridge anterior to septum low and not clearly formed.

Brachial valve interior with moderately large and deeply excavated cardinal process with narrow prosocket ridges. Adductor dividing ridges strong, anderidia protruding. Brevisseptum short, highest anteriorly but not extending to antron. Visceral region not thickened.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
AMNH 631							
152159a	8.2	?	11.0	12.6*	10.3	3.4	?
152159b	7.5	6.4	10.0	10.2*	10.1	3.0	1.6
152159c	6.9	6.2	9.3	10.2	9.2	2.8	1.6
152159d	7.0	6.1	9.5	10.4	9.7	2.8	1.7
152159e	5.7	5.0	7.2	9.2	8.4	1.9	0.7
152159f	5.6	5.0	7.0	8.4*	7.7	2.1	1.2
152159g	4.9	4.3	6.0	7.4*	6.6	2.0	1.0
152159h	8.4	6.9	11.0	10.0	10.5	3.5	2.3
152159j	7.6	6.9	9.5	11.4	10.7	2.5	1.2
152159k	10.0	8.3	12.5	14.6*	14.0	3.8	2.3
(holotype)							

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation, Skinner Ranch Formation.

LOCALITIES.—Bone Spring: AMNH 625, 631, 634; USNM 728e. Skinner Ranch (low): USNM 705a, 707g, 720e, 720g.

DIAGNOSIS.—Small *Leurosina* with hinge width usually slightly greater than midwidth and with deep brachial valve.

TYPES.—Holotype: USNM 152159k. Figured paratypes: USNM 152159-l, m; 153730a, b; 153731 a-c. Measured unfigured paratypes: USNM 152159 a-j.

COMPARISON.—This species need only be compared with those having comparatively narrow hinge such as *L. sinesulca* (Stehli), and as *L. lata*, *L. marginata*, and *L. delicata*, all new species. All the specimens of *L. vulgarica* indicate a small species, smaller than any of these named above, which differs from the latter two species in having the hinge slightly extended and in the possession of small ears. It also does not have the broad anterior flattening characteristic of *L. lata* and *L. marginata*.

The same differences will distinguish it from *L. delicata* which is broadly flattened anteriorly and generally is somewhat narrow hinged.

*Leurosina vulgarica* is smaller than *L. sinesulca* (Stehli), which occurs at about the same stratigraphic level. It appears to be somewhat higher in profile, and the brachial valve is deeper in *L. vulgarica*.

This species is rare in the Sierra Diablo as well as in the Glass Mountains. It is doubtful if this species would have been discovered in the *Scacchinella* beds were it not for the acidizing treatment, which reveals so many small or minute forms.

Genus *Mesolobus* Dunbar and Condra, 1932

*Mesolobus* Dunbar and Condra, 1932:134, 159.—Muir-Wood, 1962:79.—Williams et al., 1965:H430.

*Mesolobus? permianus*, new species

PLATE 496: FIGURES 1-7

Small, transversely rectangular in outline, hinge



widest, sides sloping slightly inward, medially slightly concave. Anterior margin broadly rounded. Anterior commissure with narrow median fold in ventral direction and broad depression in dorsal direction. Surface finely capillate.

Pedicle valve moderately and evenly convex in lateral profile; broadly convex in anterior profile, with short concave lateral slopes and trilobed dome. Umbonal region moderately swollen; sulcus broad and deep, originating at umbo and extending to front margin. Sulcus occupied medially by narrow fold originating just anterior to umbo and extending to front margin. Flanks bounding sulcus forming narrow divergent plications meeting anterolateral extremities. Ears small, obtuse, forming angle with posterior margin of about 100°.

Brachial valve moderately concave and deepest near midvalve; median broad sulcus bounded by narrow oblique plications meeting margin just anterior to ears. Median region marked by two low plications, slightly divergent, separated by shallow depression corresponding to narrow median fold of pedicle valve.

Interior unknown except for coarse pustules along inner margin.

MEASUREMENTS (in mm).—From locality USNM 703a specimen 152797 (holotype): length 7.8, brachial valve length 6.0, surface length 11.0, hinge width 10.5, midwidth 9.7, height 3.4, thickness 2.3.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITY.—USNM 703a.

DIAGNOSIS.—Small rectangular, thick-shelled *Mesolobus* (?) with strong, narrow, lateral folds.

TYPES.—Holotype: USNM 152797.

COMPARISON.—This species is readily distinguished from Pennsylvanian forms of *Mesolobus* by the narrowness and great height of the lateral plications of the pedicle valve and by the sharp narrowness of the pedicle valve median fold, which does not equal the height of the lateral plications. These characters will also distinguish the American species from *Chonetes sinuosa* (sic) Schellwien, from the Permian of the Carnic Alps, which is a much smaller species having a more sulcate fold on the brachial valve.

DISCUSSION.—It is astonishing to find this normally lower Pennsylvanian genus fairly high in the Permian. No intermediates are known in the United States and the European species mentioned above

comes from a limestone of Wolfcampian age. Nevertheless, exterior details of folding are exactly like those of the Pennsylvanian species except for the harsher contours of the Glass Mountains species. It is probable that this species represents a convergence toward *Mesolobus* evolved in late Pennsylvanian time from a stock different from that which produced *Mesolobus*.

### Genus *Quadrochonetes* Stehli, 1954

*Quadrochonetes* Stehli, 1954:309.—Muir-Wood, 1962:83.—Williams et al., 1965:H430.

Small, transversely rectangular in outline, hinge widest part; cardinal extremities produced into small ears. Strongly concavo-convex. Anterior commissure strongly folded toward brachial valve. Pedicle valve with two strong angular or subangular plications. Posterior margin with moderately long, erect spines approximately at right angles to hinge. Surface smooth.

Pedicle valve with rimlike pseudodeltidium and short interarea; beak strongly incurved and umbonal region inflated and prominent. Interior with short, wide, thin teeth; apical callosity thick; median septum short; ridge anterior to septum not strongly developed. Diductor scars long and narrow; adductor field large. Inner lateral slopes granulose.

Brachial valve interior with deeply excavated cardinal process; prosocket ridges fairly thick and long, defining narrow, slitlike sockets. Adductor dividing ridges scarcely formed; anderia small and protuberant. Brevisseptum short, confined to midvalve, not extending to antron, and usually occupying deep median trough. Visceral region narrowly thickened anteriorly and laterally but not spinose.

TYPE-SPECIES.—*Quadrochonetes girtyi* Stehli (1954:310, pl. 19: figs. 23–26); *Chonetes quadratus* Girty (1929:407, figs. 4–7).

DIAGNOSIS.—Transversely rectangular Chonetacea with a wide sulcus bordered by a strong angular to subangular plication and with brachial valve visceral region thickened but not spinose.

COMPARISONS.—The great width of the sulcus of the pedicle valve and the sharpness and strength of the bounding plications make this genus unique. It suggests *Sulcataria* Cooper and Grant, but in that genus the sulcus is not nearly so wide nor the

cardinal extremities so extended laterally. Some of the species assigned to *Leurosina*, new genus, and *Dyoros* (*Dyoros*) Stehli approach this genus in exterior form, but none has either the fold or the bounding ridges so strongly emphasized.

DISCUSSION.—This genus represents the end phases of a trend in the development of the sulcus in the smooth Chonetacea. Another unusual feature of this genus is the erect spines on the posterior margin. In this respect it is like *Undulella* Cooper and Grant, but that is the only point of resemblance.

The interior features of the pedicle valve are not unusual. The teeth are wide and strong and the apical callosity thick. The short median septum is like that of most other Late Paleozoic Chonetacea. The median ridge anterior to the septum is scarcely developed, but the strong exterior sulcus produces an interior median angulation that takes the place of a median ridge. The interior of the valve is generally strongly granulose.

The brachial valve interior produces a surprise in the nearly complete smoothness of the visceral region, especially that part on each side of the anteromedian trough. In all the other genera, the anterolateral part of the visceral region is strongly granulose or tufted by spines, as in *Dyoros* (*Dyoros*). In *Quadrochonetes* this region is much thickened but no fringe of spines is present. The outer slopes of the anteromedian part of the visceral region to the short deflected border are granulose, as are also the inner slopes bounding

the median trough. The brevisseptum in this genus is much reduced, as are most of the other structures.

### *Quadrochonetes girtyi* Stehli

PLATE 491: FIGURES 46–54; PLATE 502: FIGURES 14–33

*Chonetes quadratus* Girty (not Nikitin), 1929:407, figs. 4–7.  
*Quadrochonetes girtyi* Stehli, 1954:310, pl. 19: figs. 23–26.

Small, transversely rectangular in outline, hinge widest part, cardinal extremities making angle of 70° to 80°. Sides moderately oblique, straight or slightly rounded. Anterolateral extremities narrowly rounded. Anterior margin with broad, generally angular emargination. Anterior commissure with strong median dorsal fold; lateral commissure generally with strong dorsad wave anterior to midvalve. Posterior margin with 7 to 9 erect, moderately long spines on each side.

Pedicle valve moderately convex in lateral profile, umbonal region narrowly convex; anterior profile broadly domed, median region strongly depressed, sides short and steep. Umbonal region narrowly swollen and protruding posterior to hinge. Sulcus originating on umbo, widening and deepening to indent anterior margin broadly. Sulcus flanked by two narrowly rounded but somewhat variable plications with steep, lateral slopes nearly vertical in some specimens, but steeply sloping in others. Sulcus deep, median line impressed. Posterolateral regions strongly depressed in relation to plications bounding sulcus. Pseudodeltidium rim-like; interarea short, curved, anacline.

#### MEASUREMENTS (in mm).—*Quadrochonetes girtyi* Stehli:

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 728f							
152091a	8.6	7.3	12.0	13.8	12.0	4.6	?
152091b	8.0	7.3	11.0	11.6	10.5	4.0	3.0
152091c	7.4	5.5	11.0	12.0	10.6	3.5	?
152091d	6.8	5.7	9.0	9.7	8.2	3.2	2.4
152091e	6.0	5.1	8.5	8.5	7.7	3.1	2.3
152091f	5.6	4.7	7.5	7.3	7.4	2.9	1.4
152091g	5.1	3.9	6.5	7.3	7.0	2.5	1.7
152091h	3.9	3.0	5.0	5.8	5.3	2.0	1.4
152091i	2.9	2.3	4.0	4.4	4.2	1.4	1.4
152091j	6.0	5.0	7.5	8.0	7.8	3.1	2.2
152091k	8.3	?	10.0	9.8	9.6	3.6	?
152091l	8.8	?	11.5	11.4	11.2	4.1	?
152091m	7.8	?	10.0	10.1?	10.6	3.5	?

Brachial valve deeply concave, concavity strongest in two troughlike areas extending into protuberant, narrowly rounded anterolateral extremities. Fold originating on umbo, widening anteriorly from narrow ridge to carinate plication. Median troughs bounded by subangular ridge forming dorsal indentation in lateral commissure. Posterolateral extremities flattened. Interarea short, strongly hypercline.

Brachial valve interior with moderately large and deeply excavated tetralobed cardinal process, partially covered by convex chilidium. Antron deep; prosocket ridges extended widely, narrow and bounding slitlike sockets. Anderidia delicate and slender. Brevisseptum low and short, confined to deep trough occupying median part of valve; lateral and anterolateral margins of visceral region thickened, not spinose. Anterior and lateral slopes granulose.

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation.

LOCALITIES.—AMNH 369, 625, 628, 629; USNM 728e, 728f, 728h, 728t, 746.

DIAGNOSIS.—Transversely rectangular *Quadrochonetes* with a strong plication on each side of the sulcus which is wide and deep.

TYPES.—Lectotype: AMNH 27298/1:1. Figured paratypes: AMNH 27298/1:2–4. Figured hypotypes: USNM 152091b–c, f–i, k; 153721a–h; 153748a–c. Measured hypotypes: USNM 152091a–m.

COMPARISONS.—This species is narrower than *Q. praecursor*, new species, and has a wider sulcus and more strongly angular lateral plications than that form. This species is abundant at USNM 728f but seems to be rare elsewhere.

### *Quadrochonetes praecursor*, new species

PLATE 502: FIGURES 1–13

Small, transversely rectangular, hinge slightly narrower than midwidth; cardinal extremities right angle or slightly obtuse. Sides gently rounded. Anterior margin subtruncate to broadly emarginate. Anterior commissure broadly folded in dorsal direction. Posterior margin with about 6 erect spines on each side.

Pedicle valve fairly evenly and moderately convex in lateral profile; anterior profile broadly domed, crest broadly depressed medially, sides long and moderately strongly sloping. Umbonal region moderately swollen, not much protuberant posterior to posterior margin. Median region broadly swollen. Sulcus originating on umbo, broadening anteriorly to occupy more than half valve width and bearing deeply impressed groove along midline. Flanks bounding sulcus narrowly rounded posteriorly but becoming broadly rounded anterolaterally. Lateral slopes steep but becoming shorter and less steep where passing into umbonal slopes. Posterolateral extremities not strongly depressed.

Brachial valve moderately concave, concavity deepest bounding fold in two oblique troughs. Fold originating just posterior to midvalve, subcarinate, flattened, not strongly demarcated. Pedicle valve interior with short, strongly convex pseudodeltidium, thick apical callosity and short median septum but without ridge anterior to it.

Brachial valve interior with excavated cardinal process, thickened prosocket ridges; adductor dividing ridges not visible; brevisseptum much reduced. Visceral region swollen laterally and anterolaterally but not spinose.

#### MEASUREMENTS (in mm).—*Quadrochonetes praecursor*, new species:

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
AMNH 631							
152088a	6.5	?	8.0	10.0	10.0	2.2	?
(holotype)							
152088b	5.4	?	7.5	9.0	9.1	2.2	?
152088c	5.6	?	7.0	7.7	8.7	2.3	?
152088d	4.7	4.1	5.5	6.9	8.0	1.6	1.3
152088e	3.8	3.6	4.5	5.4	6.4	1.6	1.3

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation (immediately over the Hueco bioherm).

LOCALITY.—AMNH 631

DIAGNOSIS.—Small *Quadrochonetes* with narrow hinge and broad moderately deep sulcus bordered by low flanks.

**TYPES.**—Holotype: USNM 152088a. Figured paratypes: USNM 152088b–i, k. Measured paratypes: USNM 152088b–e. Unfigured paratypes: USNM 152088j.

**COMPARISON.**—This species is smaller than the type species and readily distinguished by the more subdued character of the plication on each side of the sulcus, which is not so deep as in *Q. girtyi* Stehli. Furthermore, the hinge is equal to or narrower than midwidth, a feature entirely unlike that of Stehli's species. The subdued character of the sulcus and flanks of the pedicle valve are reflected in similar changes in the brachial valve, which is not so deep as in *Q. girtyi*; moreover the fold is less prominent and the posterolateral extremities are not demarcated by strong oblique plications.

### LAMELLOSIINAE, new subfamily

Chonetaceans with fine concentric lamellae on the exterior.

This subfamily is placed in the Rugosochonetidae Muir-Wood (1962) because of its general resemblance to *Dyoros* (*Dyoros*), which is wide-hinged and usually ventrally sulcate. The only known genus is *Lamellosia*, a new genus from the Delaware Basin of West Texas.

#### *Lamellosia*, new genus

[Latin *lamella* (thin plate)]

This name is proposed for chonetids having a lamellose exterior formed of closely arranged concentric laminae. This is the only chonetid having this type of ornament.

**TYPE-SPECIES.**—*Lamellosia lamellosa*, new species.

Comparison with the various genera of the Chonetida is unnecessary as no other genus has this type of ornament.

#### *Lamellosia lamellosa*, new species

PLATE 497: FIGURES 36–43

Medium size for chonetid, subtrapezoidal in outline, hinge widest part; sides sloping obliquely medially and nearly straight; anterior margin somewhat narrowly rounded; anterior commissure with slight dorsal fold; interareas of unequal length, ventral length longer, slightly curved and anacline; brachial valve interarea hypercline. Posterior margin with 10 spines on each side of beak in large

adult. Surface marked by thin wavy, concentric lamellae covering all of both valves except umbonal region.

Pedicle valve moderately convex in lateral profile but forming broad, rounded dome with long sloping sides in anterior profile. Flanks depressed below median region; ears not well demarcated. Umbonal region narrowly swollen. Chilidium well developed.

Brachial valve deeply concave, conforming closely to concavity of pedicle valve, deepest medially from beak to anterior margin; lateral areas moderately concave and set off by oblique ridges; umbonal region deeply depressed.

Pedicle valve interior with plugged apex and short low median septum scarcely extending beyond delthyrial region. Muscle scars not defined; region surrounding muscle area moderately strongly granulose.

Brachial valve interior unknown.

**MEASUREMENTS** (in mm).—From locality USNM 732a, specimen 153740a (holotype) and d, respectively: length 8.5, 9.1; brachial valve length 7.3, (?); surface length 12.0, 13.0; hinge width 12.5, 16.0; midwidth 8.5, 13.0; height 3.4, 3.4; thickness 1.5, (?).

**STRATIGRAPHIC OCCURRENCE.**—Bell Canyon Formation (Hegler Member).

**LOCALITY.**—USNM 732a.

**DIAGNOSIS.**—Chonetid with lamellose exterior.

**TYPES.**—Holotype: USNM 153740a. Figured paratypes: USNM 153740b–d. Measured paratype: USNM 153740d. Unfigured paratypes: USNM 153740e, f.

**COMPARISON AND DISCUSSION.**—This is the only species of the genus known. When the shell is exfoliated, the resulting stripped area is capillate. The external ornament of thin concentric lamellae suggests that seen in some of the Plectamonitacea such as *Leangella*, described by Öpik (1933:42), and *Bimuria* Cooper (1956:764, 765).

### Subfamily CHONETINELLINAE Muir-Wood, 1962

Usually small, occasionally large, generally with deeply sulcate pedicle valve; surface smooth, costellate to costate. Brachial valve with strong fold. Interior like Rugosochonetinae.

This subfamily includes the genera *Chonetinetes* Cooper and Grant (1969) and *Chonetinella* Rams-

bottom (1952) in the Glass Mountains and Sierra Diablo; it extends up to the lower part of the Road Canyon Formation in the Glass Mountains and is present in the Bell Canyon Formation. *Chonetinetes* is placed in association with costate and costellate shells because its external form and dorsal valve are so much like those of *Chonetinella*.

### *Chonetinella* Ramsbottom, 1952

*Chonetinella* Ramsbottom, 1952:13.—Stehli, 1954:313—Muir-Wood, 1962:85.—Williams et al., 1965:H430.

Ramsbottom (1952:13) showed that the chonetids referred by many authors to *Chonetina* did not agree with the type-species. All these improperly referred species are fairly strongly costellate, whereas *Chonetina* is in actuality a smooth shell. It was necessary, then, to make a new name for the costellate species and *Chonetinella* was proposed.

R. E. King (1931) did not recognize the genus *Chonetina* in the sense used before Ramsbottom's work. He did, however, identify *Chonetes verneuillianus* (Norwood and Pratten) which was assigned later to *Chonetina* by Dunbar and Condra (1932:158). Examination of King's specimens (YPM 10792) indicates that it was originally smooth. The brachial valve is definitely smooth but the anterior part of the pedicle valve, which has been abraded, shows fine striations. The specimen probably belongs to the smooth genus *Dyoros* (*Dyoros*) (see pl. 498: figs. 38–43).

*Chonetinella* is rare in the Glass Mountains. None of the species described herein is represented by abundant specimens. Furthermore, all the species present could not be described, because of insufficient material. The genus ranges in the Glass Mountains from below the Gaptank (*Uddenites*-bearing Shale Member) through the Wolfcampian into the Decie Ranch Member (*Scacchinella* Zone) and the Road Canyon.

### *Chonetinella biplicata* (R. E. King)

PLATE 478: FIGURES 13–46

*Chonetes biplicatus* R. E. King, 1931:60, pl. 9: fig. 12a–c [not fig. 13].

*Chonetinella biplicata* (R. E. King), Stehli, 1954:315, pl. 19: figs. 16–18.

Medium for genus, transversely rectangular to

broadly elliptical in outline, hinge variable. Cardinal extremities varying from slightly acute to slightly obtuse. Sides generally slightly rounded in adult, nearly straight to sloping slightly medially in young specimens. Anterior margin quadrilobate in older shells, median two lobes small and narrow. Anterior commissure with broad, but medially indented fold toward pedicle valve. Surface finely costellate, costellae numbering 3 or 4 per mm at anterior margin of large specimen. Posterior margin marked by 4 (?) oblique spines on each side.

Pedicle valve fairly evenly convex in lateral profile, but umbonal region narrowly rounded; anterior profile a broad dome with long, moderately steeply sloping sides and narrow median indentation. Umbonal region narrowly swollen and protruding moderately posterior to hinge. Median region strongly inflated from umbo to anterior margin, sides rounded but depressed. Sulcus narrow, deep, originating on umbo and extending with little change in depth and width to narrowly indented anterior margin. Flanks bounding sulcus forming two strong plications. Lateral region moderately swollen and depressed below rounded flanks bordering sulcus. Posterolateral extremities not conspicuous. Interarea moderately long, anacline. Pseudodeltidium short and rimlike.

Brachial valve deeply concave, maximum concavity forming trough from beak to margin; margin slightly deflected in dorsal direction. Sides broadly flattened and separated from deep median region by oblique fold toward dorsal side. Posterolateral extremities flattened. Fold originating close to beak, narrow and somewhat keeled posteriorly, becoming broader and more rounded anteriorly. Interarea short, hypercline.

Pedicle valve with apex plugged by thick callosity involving short median septum; median ridge strong, extending to about midvalve; anterior to this point, exterior sulcus continuing as strong ridge to anterior margin. Teeth very short and wide. Inner lateral slopes strongly granulose.

Brachial valve interior with small excavated cardinal process and wide, slitlike sockets bounded by thin prosocket ridges. Adductor dividing ridges not conspicuous. Brevisseptum reduced, extending to about midvalve, terminating at posterior end of deep trough formed by exterior fold. Visceral region not strongly thickened, strongly granulose anteromedially.



## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 728f							
151868a	11.7	9.5	15.5	16.3	16.0	4.9	2.9
AMNH 631							
151859a	10.7	8.7	14.5	15.2*	15.0	5.0	3.2
151859b	10.0	8.0	13.5	14.0*	13.9	3.8	2.2
151859c	8.2	6.5	12.0	11.8*	11.9	4.0	2.5
151859d	7.1	5.9	10.5	7.8?	9.6	3.3	2.2
151859e	8.5	6.9	11.5	12.6	11.8	3.9	2.1
USNM 705a							
151853a	9.3	7.1	13.0	10.0?	12.7	4.5	3.5
151853b	8.9	7.0	12.5	12.8	11.5	4.2	2.6
151853c	6.8	6.0	10.0	10.5	10.2	3.0	1.8
USNM 720e							
151866	9.4	7.4	13.0	12.4	12.3	4.0	2.9

STRATIGRAPHIC OCCURRENCE.—Lower Bone Spring Formation, Skinner Ranch Formation (base). Hess Formation (Taylor Ranch Member).

LOCALITIES.—Bone Spring: AMNH 625, 631; USNM 728e, 728f, 728t. Skinner Ranch (base): USNM 705a, 709u, 720e, 720g, 724q. Taylor Ranch: USNM 716n.

DIAGNOSIS.—*Chonetinella* with strong fold and sulcus, anterior margin strongly lobate.

TYPES.—Holotype: YPM 10824. Figured hypotypes: USNM 151852, 151853b, 151856, 151868a, 153681a–i. Measured hypotypes: USNM 151853a–c, 151859a–e, 151866, 151868a.

COMPARISONS.—This species is distinguished from all others described herein by the strong sulcus that is further emphasized by the strong bounding plicae. On the brachial valve the fold is narrow but subcarinate and is emphasized by a groove on each side. These make two small protuberances on the anterior end of the fold and sulcus. In addition to the two strong plicae on each side of the sulcus, large specimens develop on the flanks a distinct but broad plication which makes a distinct lateral lobe on each side, and tends to give the shell a quadrilobed effect.

DISCUSSION.—The tooth in the pedicle valve is extended for a considerable distance along the hinge edge. In many specimens a thickening appears under the palintrope to help support these teeth. The apical callosity is large and thick in the old pedicle valves. The exterior sulcus forms a

prominent median ridge that serves in lieu of a septum, which is not developed.

The adult brachial valve interior is deeply grooved anteriorly and the anterolateral ends of the visceral disc are thickened and elevated. The median septum is thick, but not high, and is strongest distally where it stands at the posterior end of the deep median trough. The interior is strongly granulose to spinose.

The species was first described from the Diablo Plateau region and one specimen (T10686) from the Glass Mountains was assigned to it by King. This specimen, however, appears to have nothing to do with this Diablo Plateau species, as it comes from a part of the section (Lenox Hills Formation) from which we were unable to relocate it. Typical specimens, which share all the internal as well as the external characteristics, occur in the Skinner Ranch (*Scacchinella* Zone) at three places (USNM 705a, 720e, and 720g). The species is very rare at these places and is generally not well preserved. Rarer still is the single specimen from the Taylor Ranch Member, which helps to indicate the relationship between this member and the lower part of the Skinner Ranch Formation.

*Chonetinella ciboloensis*, new species

Small for genus, transversely rectangular in outline, hinge widest part; sides nearly straight,

sloping slightly medially; anterior margin rounded and slightly indented medially; ears slightly acute; anterior commissure with slight, narrow dorsal fold; costellae numbering 5 per mm near front margin of holotype.

Pedicle valve fairly strongly convex, most so in posterior region; anterior profile somewhat narrowly domed, with slight median indentation, sides

fairly steeply sloping. Umbonal region swollen. Sulcus originating on umbo, narrow, shallow and extending to anterior margin, indenting it slightly. Interarea curved, long, anacline.

Brachial valve deeply and evenly concave; ears marked off by narrow oblique, gently concave ridge. Fold barely perceptible. Interarea hypercline.

Interior not known.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
AMNH 703							
153752a	5.9	5.0	9.0	7.4	6.7	3.1	1.7
153752b	7.2	5.5	10.0	8.8	8.0	3.7	2.2
(holotype)							
153752c	6.1	5.0	8.5	7.3?	?	3.0	1.5

STRATIGRAPHIC OCCURRENCE.—Cibolo Formation (Breccia Zone of Udden).

LOCALITIES.—AMNH 703 = USNM 728-1.

DIAGNOSIS.—Small, narrowly rectangular *Chonetinella* with narrow sulcus and poorly defined fold.

TYPES.—Holotype: USNM 153752b. Figured paratype: USNM 153752a. Measured paratypes: USNM 153752a, c. Unfigured paratypes: USNM 153752c-f.

COMPARISON.—This small species need be compared only to *C. parva* and *crassiparva*, both new species, and to *C. spinolirata* (R. E. King). *Chonetinella ciboloensis* is a larger and wider species than *C. parva* but it has a wider and stronger sulcus than that species. It is larger than *C. crassiparva* but has a less strongly developed sulcus, is less deeply concave, and has a better development of the ears. It differs from *C. spinolirata* in having different proportions and in being less deeply sulcate, with a less well-developed fold on the brachial valve.

#### *Chonetinella costellata*, new species

PLATE 479: FIGURES 1-23

*Chonetes granulifer* R. E. King (not Owen), 1931:60, pl. 9: fig. 14.

Fairly large for genus, wider than long, subrectangular in outline. Hinge widest part; cardinal extremities drawn into sharp, small points. Sides

slightly concave just anterior to ears, slightly rounded or sloping slightly medially toward anterior. Anterior margin broadly rounded. Anterior margin of adults not indented medially. Anterior commissure not folded. Surface finely costellate, costellae subdued and crowded, numbering 5 per mm at front margin. Posterior margin with 10 oblique, slender spines on each side of the beak.

Pedicle valve with lateral profile evenly and moderately convex, most convex near midvalve. Anterior profile forming broad dome with long, steeply sloping sides and slightly indented crest. Umbonal region not strongly extended posterior to hinge and broadly swollen. Median region strongly swollen. Sulcus originating on umbo, narrow and shallow, not always clearly discernible. Flanks bounding sulcus only slightly swollen. Anterolateral and lateral slopes steep. Umbonal slopes to cardinal extremities short and steep. Cardinal extremities demarcated by abrupt change of umbonal slope. Interarea short, anacline. Pseudodeltidium short and rimlike.

Brachial valve deeply concave, concavity occupying most of valve with short, moderately steep lateral slopes. Posterolateral extremities flattened and deflected. Anterior slope gentle and short.

Pedicle valve interior with delthyrium plugged by thick callosity; teeth wide and slender; median ridge elevated and extended nearly to midvalve.

Inner lateral slopes near margins strongly granulose.

Brachial valve interior with low, wide, excavated cardinal process and thin, wide, prosocket ridges defining slitlike sockets. Adductor dividing ridges

not well formed except on old specimens; anderidia well formed and protruding. Brevisseptum low and reduced, not reaching the antron. Anteromedian area not troughlike. Visceral area not greatly thickened and marked by coarse granules.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 701							
151876a	7.9	6.8	10.5	10.1	10.6	3.7	1.9
151876b	8.0	6.8	10.7	11.4	11.0	3.7	1.7
151976c	7.1	6.2	10.0	12.2	10.2	3.0	1.7
151876d	6.8	5.9	9.0	9.8*	9.2	2.9	1.5
151876e	5.7	4.9	8.0	8.6	8.0	2.5	1.6
151876f	9.3	7.5	13.0	14.2	12.8	4.9	?
(holotype)							
151876g	9.7	7.8	13.0	14.0*	12.0	4.4	?

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation (*Uddenites*-bearing Shale Member), Neal Ranch Formation.

LOCALITY.—Gaptank Formation: USNM 705ca. *Uddenites*: 701e, 701p, 701v, 703p. Neal Ranch: 701, 701c, 706x.

DIAGNOSIS.—Fairly large *Chonetinella* with fine costellae and poorly developed fold and sulcus.

TYPES.—Holotype: USNM 151876f. Figured paratypes: USNM 151876a, b, e, g, h. Measured paratypes: USNM 151876a–e, g. Unfigured paratypes: USNM 151876c, d.

COMPARISONS.—This species differs from any other *Chonetinella* from the Permian rocks under discussion in its narrow and shallow sulcus and the poor development of a fold on the brachial valve. In these respects too it is different from any of the described species from Pennsylvanian rocks.

DISCUSSION.—The highly domed form and the even, strong development of costellae, together with the presence of the narrow sulcus, make the assignment of this species to *Chonetinella* the only one possible. Inside the pedicle valve the teeth are wide and short, running parallel to the hinge. Although the apical callosity is thick, the median septum and ridge are delicate. As a matter of fact, the entire shell with its fine costellae gives the impression of fragility.

A departure from the normal *Chonetinella* appears inside the brachial valve. The region

anterior to the distal end of the low median septum is not deeply sulcate as usual in this genus. The anterolateral extremities of the visceral region are therefore not elevated and thickened. In spite of its general delicate appearance, the brachial valve interior is strongly granulose.

This species is rare in the Neal Ranch Formation, the best and typical specimens occurring in the upper 15 feet of the Gray Limestone Member of P. B. King (USNM 701). Specimens from the *Uddenites*-bearing Shale Member of the Gaptank are also assigned here, as well as specimens from shale in the Gaptank Formation on the flank of Leonard Mountain.

*Chonetinella crassiparva*, new species

PLATE 500: FIGURES 1–10

Small, length and width about equal, outline pentagonal; hinge usually widest part, cardinal extremities produced into small ears. Sides nearly straight to sloping slightly in medial direction. Anterior margin narrowly rounded. Anterior commissure with small dorsad indentation medially. Surface costellate, costellae numbering 4 per mm at front margin of adults; costellae bifurcating in three generations; costellae bearing sporadic cavities or pores suggesting position of broken spines. Posterior margin with 2 (?) spines on each side of beak.

Pedicle valve strongly and fairly evenly convex, maximum near midvalve; anterior profile narrow dome with steep sides and dimpled crest. Umbo narrowly swollen and protruding conspicuously posterior to hinge. Median region greatly inflated. Sulcus narrow, deep, indenting margin, originating on umbo and extending to anterior margin. Flanks narrowly rounded and precipitous. Posterolateral extremities slightly deflected and convex. Interarea short, anacline.

Brachial valve deeply concave, concavity forming deep trough from beak to anterior margin, there forming ventral fold in commissure. Fold prominent, originating almost at beak, subcarinate to narrowly rounded and widening anteriorly to the margin. Sides sloping moderately medially. Postero-

lateral extremities deflected in dorsal direction and flattened.

Pedicle valve interior with delthyrium plugged by thick callosity; median septum forming high and strong partition in posterior third, joining ridge formed by exterior sulcus in anterior two-thirds. Teeth slender, paralleling hinge margin. Inner lateral slopes coarsely granulose.

Brachial valve interior with small excavated cardinal process; prosocket ridges slender; anderidia small and protruding, but adductor dividing ridges not developed. Brevisseptum short, not extending posteriorly to antron and overhanging anteriorly deep trough extending from midvalve to front margin, bounded by high ridge on each side; visceral disc with rows of thick, spinelike taleolae.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 701							
151883a	5.0	4.3	7.0	5.4	5.5	2.9	1.8
151883b	4.9	4.2	7.0	5.0	5.2	2.9	2.0
(holotype)							
151883c	4.8	3.7	7.5	4.9	4.8	3.0	2.1
151883d	4.3	3.6	6.5	4.9	4.7	2.7	1.8
151883e	4.0	3.3	6.0	5.0	4.3	2.6	1.6

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (upper 15 feet of King's bed 2).

LOCALITY.—USNM 701.

DIAGNOSIS.—Small quadrate *Chonetinella* with strong costellae, deep sulcus on the pedicle valve and strong fold.

TYPES.—Holotype: USNM 151883b. Figured paratypes: USNM 151882a, b; 151883a, d, e. Measured paratypes: USNM 151883a, c–e. Unfigured paratype: USNM 151883c.

COMPARISON.—This species is characterized by its small size and square outline. It is thus necessary to compare it only with the other species of small size that have been described—*C. spinolirata* (R. E. King) and *C. parva*, new species. *Chonetinella crassiparva* is distinguished from *C. spinolirata* in its square outline and moderately deeply concave brachial valve and somewhat stronger costellae. King's species is definitely transverse and the brachial valve is more shallow than that of *C. crassiparva*. The fold of the latter is also stronger than that of King's species.

*Chonetinella parva* has the same general characteristics of *C. crassiparva* in outline and profile but is a larger species without a pronounced fold in the brachial valve and has a shallower brachial valve and finer costellae.

DISCUSSION.—These tiny shells show no interior features unusual for the genus. The brachial valve is deeply sulcate in the anterior median part, as usual for the genus. This species is rare and it is doubtful if it would have been found among the limestones except for the fact that the specimens are silicified.

#### *Chonetinella gerontica*, new species

PLATE 154: FIGURES 8–12 (volume II); PLATE 501: FIGURES 5–24

Medium size for genus, wider than long, hinge narrower or greater than midwidth, depending on development of ears; cardinal extremities acute in young but narrowly rounded in old specimens; sides concave to rounded depending on age of specimen; anterior margin broadly rounded; anterior

commissure with or without faint dorsal fold at middle; surface finely costate, costae numbering 5 per mm at front margin; posterior margin with at least 6 spines on each side.

Pedicle valve strongly convex in lateral profile and strongly domed in anterior profile, crest of dome having slight median depression, sides very steep. Umbonal region strongly swollen; shallow, narrow sulcus originating on umbo, making little impression on anterior margin. Interarea long, curved, orthocline to anacline. Pseudodeltidium well developed when preserved, filling almost half of delthyrium.

Pedicle valve interior with thick apical callosity;

median septum reduced to small point; median elevation formed by sulcus much thickened and extending almost to anterior; diductor scars deeply impressed, wide and long occupying nearly whole posterior half; anterior margin slightly flattened and pustulose, as is most of interior (outside muscle scars).

Brachial valve interior greatly thickened; cardinal process swollen but with small antron; prosocket ridges thick; median septum thick, often obscured by shell deposit; adductor dividing ridges mostly buried but anderidia greatly thickened to form small nodes; lateral regions strongly thickened.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 732j							
153753a	10.6	8.5	14.5	12.6*	12.8	4.8	2.8
(holotype)							
153753d	12.0	?	18.5	12.3	13.8	5.2	?
153753g	9.6	7.8	13.5	13.7	11.9	4.5	2.2
154417a	11.5	?	18.0	14.2	15.0	5.7	?
154417c	8.5	7.0	12.0	11.0	10.8	4.0	2.7
154417d	11.0	?	16.0	12.2	13.2	5.5	?
154417e	?	10.6	?	14.0	15.2	?	?

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITY.—USNM 732j.

DIAGNOSIS.—Medium-sized, strongly convex, fine-lined *Chonetinella* with greatly thickened interior.

TYPES.—Holotype: USNM 153753a. Figured paratypes: USNM 153753b–f; 154417b, c. Measured paratypes: USNM 153753d, g; 154417a, c–e. Unfigured paratypes: USNM 153753g; 154417a, d–e.

COMPARISON.—This species suggests *C. victoriana* (Girty) in its size and general configuration but is more finely costellate and has a much less well developed sulcus and fold. It is quite unlike any other species.

DISCUSSION.—This species is not entirely typical of the genus because of the greatly thickened interior. The fineness of the costellae raises the suspicion that these may be simply interior costellae of decorticated shells. Some of the specimens are very badly worn but one of them (USNM 154417c) seems to be very well preserved. This is the latest

development of this genus known and it has not been found in intervening strata in the Glass Mountains or in the Sierra Diablo except for a single small adult (USNM 155052) from the Cutoff Shale Member of the Bone Spring Formation near Cutoff Mountain.

#### *Chonetinella magna*, new species

PLATE 479: FIGURES 24–45

Large for genus, transversely rectangular in outline with hinge slightly narrower than or slightly wider than midwidth; cardinal extremities slightly deflected. Sides moderately rounded; anterior margin broadly rounded and slightly indented medially. Anterior commissure with faint dorsal fold. Surface costellate, costellae bifurcating in 4 or 5 generations, somewhat fasciculate at anterior, numbering 10 to 12 in 5 mm at front margin. Posterior spines not exactly determined but in excess of six on each side.



Pedicle valve strongly convex in lateral profile, most convexity at umbo; anterior profile a high, steep-sided dome with narrow notch at crest. Umbonal region greatly swollen and extended strongly posterior to hinge. Median region strongly swollen. Sulcus originating on umbo, narrowly V-shaped and nearly uniform in depth and width throughout its length from umbo to margin, indenting margin slightly. Flanks bounding sulcus broadly rounded, swollen, and with steep sides. Anterior slope steep. Interarea curved, anacline to orthocline.

Brachial valve strongly concave, maximum depth in umbonal region. Sides and anterior sloping moderately toward middle; posterolateral extremities flattened but not clearly demarcated by plications. Interarea short and hypercline. Fold originating just anterior to umbo, low and narrow, inconspicuous.

Pedicle valve interior with wide and short teeth having broad fossettes; apical callosity thick; median septum short and confined to apical region, continued anteriorly as obscure ridge.

Brachial valve with excavated cardinal process and wide slender prosocket ridges defining slitlike sockets; adductor dividing ridges including protruding anderidia. Brevisseptum short, confined to anterior median sulcus; visceral region swollen and marked by rows of stout spines.

MEASUREMENTS (in mm).—Thickness unmeasurable.

	<i>brach- ial valve length</i>	<i>sur- face length</i>	<i>hinge width</i>	<i>mid- width</i>	<i>height</i>	
AMNH 696						
151885a	15.2	?	21.0?	19.2*	21.0*	5.9
151885b	12.9	?	18.0?	14.6*	15.6*	5.2
151885c	8.7	?	13.0?	11.8*	12.6*	3.7
USNM 725c						
151884a	15.8	?	21.0	18.5	16.8	5.8
151884b	12.3	?	18.0	16.4	15.4	5.3
151884c	13.5	?	20.0	18.0	18.0	5.8
151884d	12.8	?	17.0	15.2	16.0	5.0
(holotype)						
151884e	?	11.0	?	17.4*	19.4	?

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation (100 feet above base).

LOCALITIES.—AMNH 696; USNM 725c.

DIAGNOSIS.—Large, strongly costellate *Chonetinella* with uniformly narrow sulcus.

TYPES.—Holotype: USNM 151884d. Figured paratypes: USNM 151884b, c, e, h, j, k. Measured paratypes: USNM 151884a–c, e, 151885a–c. Unfigured paratypes: USNM 151884a, f, g, i, 151885a–c.

COMPARISON.—This species is unique in the genus for its large size and strong fasciculate ornament. No specific comparison is needed.

DISCUSSION.—This species has so far been seen in the Bone Spring Formation only at the north end of the Baylor Mountains. It is not common, and first rate specimens are difficult to obtain.

The interior details of both valves seem characteristic of the genus. The teeth are wide and parallel the hinge edge, as usual, and the septum and median ridge are reduced. Granules appear on the interior flanks in definite rows. In the brachial valve the anteromedian trough at the front of the modestly developed median septum is present. The anterolateral parts of the visceral region are thickened and strongly granulose. One adult brachial valve interior has the antron under the cardinal process filled by shell material, but it is usually is open and small.

### *Chonetinella parva*, new species

PLATE 479: FIGURES 46–67

Small, rectangular, slightly wider than long, hinge equal to or slightly wider than midwidth; cardinal extremities nearly right angle or slightly acute. Sides nearly straight; anterior margin narrowly rounded, anterior commissure unfolded. Surface multicostellate, costellae numbering 5 to 6 per mm at front margin. Posterior margin with 4 (?) spines on each side.

Pedicle valve strongly and unevenly convex in lateral profile, maximum curvature in posterior half, anterior half moderately convex; anterior profile a narrowly compressed dome with precipitous sides. Umbo swollen and protruding considerably posterior to hinge. Median region strongly inflated. Sulcus originating on umbo, shallow, narrow and poorly defined, disappearing at midvalve in some specimens but nearer anterior margin in others. Posterolateral extremities slightly deflected but poorly defined. Interarea long, curved, anacline.

Brachial valve deeply concave, maximum concavity extending as trough from beak to front margin, commissure deeply bowed in ventral direction. Sides

sloping steeply to middle; posterolateral extremities flattened and deflected in ventral direction. Inter-

area short and hypercline. Fold difficult to discern. Interiors unknown.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness <sup>c</sup>
USNM 701e							
151870a	6.1	5.0	9.0	6.7	6.5	3.2	2.0
151870b	6.1	5.3	8.8	6.0	5.7	3.6	2.2
(holotype)							
151870c	6.2	5.3	9.0	5.9	6.3	3.1	2.1
151870d	5.9	5.0	8.5	6.3	6.2	3.2	2.1
USNM 701q							
151872a	5.0	4.4	7.0	5.9	5.5	3.0	1.9
USNM 705ca							
151873a	4.4	4.0	6.5	4.7	4.9	2.6	1.3

STRATIGRAPHIC OCCURRENCE.—Gaptank Formation and *Uddenites*-bearing Shale Member.

LOCALITIES.—Gaptank: 705ca. *Uddenites*: 701e, 701q.

DIAGNOSIS.—Small *Chonetinella*, nearly square in outline, deeply concave on the dorsal side and with obscure fold and sulcus.

TYPES.—Holotype: USNM 151870b. Figured paratypes: USNM 151870a, b; 151872a, b. Measured paratypes: USNM 151870a, c, d; 151872a; 151873a. Unfigured paratypes: USNM 151870c, d; 151873a.

COMPARISONS.—*Chonetinella parva*, because of its small size, need be compared only to *C. crassiparva*, new species, and *C. spinolirata* (R. E. King). It differs from the former in its larger size, relatively finer costellae, and the poor development of the fold on the brachial valve, as well as in having a shallower brachial valve. It differs from *C. spinolirata* in its proportions, being almost square, whereas King's species is distinctly transverse and has a well-defined fold on the brachial valve.

DISCUSSION.—Unfortunately no interiors of this species are available. It is rare and difficult to find because it is so small, and no interiors have appeared in any etched material from the lower part of the Wolfcampian or underlying Gaptank.

It seems odd that a group of species as small as these should appear in this one region. It might be suspected that *C. spinolirata* is really a young form of *C. parva* but this seems unlikely because the two species were taken at widely different levels. King's type specimen of *C. spinolirata* is reported from

bed 12 (of P. B. King) of the Neal Ranch Formation but *C. parva* comes from the *Uddenites*-bearing Shale Member.

*Chonetinella spinolirata* (R. E. King)

PLATE 478: FIGURES 47–51

*Chonetes spinoliratus* R. E. King, 1931:63, pl. 9: figs. 15, 16.

Shell small, subrectangular in outline; length equal to about two-thirds width; sides rounded; anterior margin probably broadly rounded; hinge straight, not quite equal to maximum width at about midlength; cardinal extremities forming slight ears; surface costellate, about five costellae per mm on margin. Costellae of both valves with short spines.

Pedicle valve strongly convex in lateral profile; strongly domed in anterior profile, crest of dome indented by narrow sulcus, slopes steep and concave to margins. Umbo narrowly swollen, swelling extending to anterior margin; median sulcus originating on umbo, narrow and deep, extending to front margin with little change in width and marked medially by single costella. Flanks narrowly rounded; small, convex ears set off by steep slopes in posterolateral areas. Interarea moderately long, curved, anacline. Beak small, overhanging the interarea; pseudodeltidium narrow rim on delthyrial edge.

Brachial valve deeply concave, most concave in median region from umbo to margin; posterolateral

extremities flattened to form slightly concave ears; medial region marked by narrow, low fold corresponding to narrow ventral sulcus. Interarea shorter than ventral one, hypercline.

MEASUREMENTS (in mm).—From R. E. King locality 91a, specimen YPM 10825 (holotype): length 4.5, brachial valve length 4.2, surface length 6.5, midwidth 6.2\*, hinge width 5.8, height 2.6, thickness 2.0.

STRATIGRAPHIC OCCURRENCE.—Neal Ranch Formation (bed 12 of King).

LOCALITY.—R. E. King locality 91a.

TYPES.—Holotype: YPM 10825. Figured paratype: T 10588. Figured specimen: YPM 10829.

DIAGNOSIS.—Small transverse *Chonetinella* with scattered small spines on the costellae, a deep sulcus in the pedicle valve, and a fairly strong fold in the moderately deep brachial valve.

COMPARISONS.—This species is one of several small *Chonetinellas* occurring in the late Pennsylvanian and early Permian. This species differs from *C. parva* in having a more transverse shell and a fairly well-developed fold in the brachial valve. It differs from *C. crassiparva* in having a less well developed fold on the brachial valve which is shallower than that of *C. crassiparva*.

DISCUSSION.—King mentions a specimen from locality 175a which may belong to *C. parva* rather than *C. spinolirata*, since it comes from yellow-brown limestone underlying the Gray Limestone Member (bed 2) and thus comes from the *Uddenites*-bearing Shale Member.

The type specimen of the variety of this species described by R. E. King as *Chonetes spinoliratus diabloensis* was regarded by Stehli as a young specimen of *Chonetinella victoriana* (Girty). Stehli's assignment has been confirmed by us in comparing King's type with many young specimens of Girty's species. (See pl. 478: figs. 52–56 for *C. spinoliratus diabloensis* (R. E. King).)

### *Chonetinella victoriana* (Girty)

PLATE 478: FIGURES 52–56; PLATE 480: FIGURES 1–31; PLATE 500: FIGURES 13–19

*Chonetes victoriana* Girty, 1929:410, pl. [no number]: figs. 1–3.

*Chonetes spinoliratus diabloensis* R. E. King, 1931:63, pl. 9: fig. 23.

*Chonetinella victoriana* (Girty) Stehli, 1954:314, pl. 19: figs. 19–22.

Large for genus, subpentagonal to subrectangular in outline; hinge widest part but variable; cardinal extremities usually acute and forming small ears but in some specimens rounded or obtuse. Sides generally faintly concave just anterior to ears but straight and sloping slightly medially; sides gently rounded in specimens with obtuse posterolateral extremities. Anterior margin usually somewhat narrowly rounded but medially indented in some specimens and lobate in large old shells. Anterior commissure with narrow dorsal fold near midvalve. Surface costellate, costellae increasing by bifurcation in four or five generations and producing moderate fasciculation. Costellae numbering about three per mm at front margin of large specimens. Umbonal costellae strong and coarse, anterior ones fine. Costellae marked medially by distant pores, remnants of "hollow spines." Posterior margin marked by as many as eight short, oblique spines on each side.

Pedicle valve unevenly convex in lateral profile, umbonal region narrowly curved, but anterior to umbo moderately convex, with maximum reached near midvalve; anterior profile narrowly domed, with long, steeply sloping sides and narrowly indented crest. Umbonal region elongate, narrowly swollen and visible in dorsal view; median region strongly swollen, with steep lateral and anterior slopes.

Sulcus originating on umbo, narrow, deep, expanding only slightly and usually forming narrow indentation of margin. Flanks narrowly rounded and steep-sided. Posterolateral extremities gently convex and demarcated by abrupt change of slope. Large, old shells with anterolateral lobation. Interarea short, curved, anacline; pseudodeltidium a short, convex rim over delthyrial margin.

Brachial valve with deep median region and steeply sloping sides; anterior with gentle slope medially; fold originating on umbo, narrow, not strongly elevated and indenting anterior margin; flanks, bounding sulcus, troughlike, moderately deep. Posterolateral extremities flattened and demarcated by oblique dorsal fold of shell; interarea short, strongly hypercline.

Pedicle valve interior with median septum engulfed by apical callosity almost completely plugging delthyrium; median ridge narrow, moderately elevated, emphasized in height by occupying crest of median fold produced by exterior sulcus, reach-

ing almost to anterior margin. Teeth short but unusually wide, with wide shallow fossettes. Inner lateral slopes strongly granulose.

Brachial valve interior with small thick, rounded and excavated cardinal process; antron usually small, filled in some specimens. Prosocket ridges

wide, slender, defining long, slitlike sockets. Adductor dividing ridges long and slender; anderidia well developed, protruding; brevisseptum short, reaching anteriorly to about midvalve but not reaching antron. Visceral region not swollen, strongly granulose medially, becoming less so anterolaterally.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 728f							
151863a	11.5	?	17.0	14.6*	13.8	5.1?	?
151863b	10.7	8.0	15.5	14.3	13.5	6.0	4.0
151863c	10.7	8.6	15.5	13.7	12.8	4.9	3.9
151863d	9.9	8.3	14.5	13.8	13.6	4.9	3.7
151863e	9.7	7.6	14.0	13.0	12.7	4.3	3.2
151863f	8.0	6.8	12.5	10.8	10.5	3.9	2.7
151863g	7.7	6.6	11.5	10.0	9.9	3.8	2.7
151863h	6.9	5.9	10.5	10.2	9.4	3.8	2.2
151863i	6.8	5.8	10.0	10.0	8.9	3.6	2.6
151863i'	6.4	5.3	9.0	8.4*	8.6	3.0	2.5
151863j	5.6	4.8	8.0	7.9	7.6	2.7	1.9
151863k	5.1	4.5	7.3	7.6*	7.0	2.8	1.8
151863l	4.3	3.8	5.5	6.5	5.8	2.3	1.4
151863m	3.4	2.8	4.0	5.2	5.0	1.7	1.3
151863n	2.6	2.1	3.0?	4.0	3.5	1.2	0.7
155139	8.7	?	13.0	11.8	10.8	4.9	?
(holotype)							

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation (lower).

LOCALITIES.—AMNH 628, 629; USNM 728e, 728f, 728h, 745, 746.

DIAGNOSIS.—Subrectangular *Chonetinella* of moderate to large size with shallow sulcus on pedicle valve and low fold on brachial valve.

TYPES.—Holotype: USNM 155139. Figured hypotypes: USNM 153683a–g, k, l. Measured hypotypes: USNM 151863a–n.

COMPARISONS.—This species attains the size of *C. biplicata* (R. E. King) but is not strongly lobed at the anterior. It differs from *C. costellata*, new species, in having stronger costellae, a deeper sulcus, and a stronger fold on the brachial valve. It is also more strongly umbonate than the Wolfcampian species. It is distinguished from most described Pennsylvanian species in its narrow, non-expanding sulcus and the narrow, inconspicuous fold. An undescribed species from the Devils Kitchen Formation of Oklahoma is similar to *C. victoriana* in size, ornament, and in the develop-

ment of the pedicle valve sulcus, but is wider and differently proportioned than the Diablo Plateau species.

DISCUSSION.—*Chonetinella victoriana* is abundant in the Diablo Plateau at USNM 728f. The silicification of this species at this place is very faithful and yields specimens ideal for the study of interior details. Inside the pedicle valve the teeth are wide as usual and are strengthened under the palintrope by deposit of shell substance. This deposit is frequently notched laterally to help the tooth lock with the prosocket ridge. The apical callosity is small and the pseudodeltidium is small, forming a somewhat elevated rim around the posterior angle of the delthyrium. The septum is modestly developed but the narrow sulcus of the exterior is revealed as a low, carinate ridge extending almost to the anterior margin.

The brachial valve has a small excavated cardinal process and a low median septum that reaches its crest at the head of the narrow shallow groove which divides the visceral region medially. The ad-

ductor dividing plates are long and slender and slightly elevated. The anterolateral areas of the visceral region are somewhat thickened and strongly granulose.

Although *Chonetinella biplicata* (R. E. King) which occurs with *C. victoriana* in the Sierra Diablo, is found also in the Glass Mountains, its companion has not yet been taken from equivalent beds in the Glass Mountains.

*Chonetes spinoliratus diabloensis* R. E. King, a small coarse-ribbed shell from the Bone Spring Formation, was referred by Stehli (1954:314) to Girty's species. Comparison of King's type specimen with numerous young specimens of *C. victoriana* amply confirms Stehli's assignment.

### *Chonetinella* species undetermined

PLATE 480: FIGURE 36; PLATE 500: FIGURES 11, 12

Several species of *Chonetinella* are represented by insufficient specimens for description. These are arranged by formation.

SPECIES 1.—A specimen (USNM 152793) was taken from Bed 12 of Cooper (14 of P. B. King) at USNM 706x. It is a large, transverse species, strongly umbonate and moderately strongly costellate (four costellae per mm) but with a deep and narrow sulcus. Measurements (in mm): length 7.3, surface length 9.5, hinge width 12.4\*, midwidth 10.6, height 3.2.

SPECIES 2 (Plate 480: figure 36; Plate 500: figures 11, 12).—A second species is represented by two specimens (152790a, b) from USNM 701 (upper 15 feet of Bed 2 of P. B. King). This is a small strongly convex, transverse species with medially sloping sides and narrow sulcus. Pedicle valves only are known. The costellae number about seven per mm at the front margin. Measurements (in mm): length 6.5, surface length 9.0, hinge width 9.2, midwidth 8.8, height 3.0.

SPECIES 3.—Three specimens of *Chonetinella* (152791a–c) were collected from the Lenox Hills ammonite bed at USNM 715. Only one of these (152791a) is an adult. It is nearly square, the width slightly greater than the length. It has a narrow, slitlike sulcus, and the costellae are variable but number about four per mm at the front margin. Measurements (in mm): length 7.2, width 8.3.

SPECIES 4.—Two specimens of a small, deeply

sulcate *Chonetinella* (152792), from the lower Skinner Ranch Member at USNM 715v, are suggestive of *C. parva* and *C. ciboloensis* but intermediate in size.

SPECIES 5.—A specimen (155052) from the Cut-off Member of the Bone Spring Formation at AMNH 678 represents a small species similar to the small ones from the Wolfcamp. Wide-hinged, with acute cardinal extremities, it is strongly convex and deeply sulcate and is covered by fine radii. Measurements (in mm): length 5, hinge width 7.

### Genus *Chonetinetes* Cooper and Grant, 1969

*Chonetinetes* Cooper and Grant, 1969:3.

Small, deeply concavo-convex, pedicle valve strongly inflated; hinge forming widest part, sides sloping medially or nearly vertical to hinge. Ears strongly developed. Posterior marginal spines moderately long, oblique to nearly erect. Anterior commissure with minute dorsal fold, or unmodified in late adult stages. Pseudodeltidium strong, long and narrowly arched. Surface smooth except for concentric lines of growth and growth interruptions. No radial marks.

Pedicle valve with narrow and shallow to moderately deep sulcus, strongest on umbo, reaching anterior margin in young specimens or small species, but obliterated in late adult stages of type species. Brachial valve deeply concave and marked by obscure, narrow, low fold reaching anterior margin in some specimens but not in others, especially in type species.

Pedicle valve interior with delthyrial cavity deep; median septum short, and strong, proximally buried in callus, anteriorly reduced to ridge extending to about midvalve. Areas marginal to visceral region strongly granulose.

Brachial valve interior with cardinal process facing posterodorsally; cardinal process large, triangular, with myophore narrowly bilobed medially and with median element protruding distally and bounded by lateral plates or apically covered by chilidial plates. Antron deep; brevisseptum best developed at midvalve, not reaching antron, occupying deep groove between elevated, somewhat conical areas at anterolateral portions of visceral region. Adductor field small, surrounded by thickened shell; anderidia erratically developed; conical



areas marked by thick taleolae aligned in well-defined rows but usually discontinuous and not forming septa.

TYPE SPECIES.—*Chonetinetes reversus* Cooper and Grant (1969:4, pl. 3: figs. 1–7).

DIAGNOSIS.—Small, wide-hinged Chonetacea having the fold and sulcus best developed in the umbonal region and with subconical mounds of taleolae on each side of the visceral region toward the anterolateral margins.

COMPARISONS.—This genus has the exterior form of *Anoplia* Hall and Clarke, *Anopliopsis* Girty, and *Chonetina* Krotov, all of which are smooth externally. It differs from the first two in having a well-developed spine row along the posterior margin, very prominent ears, and a different interior of the brachial valve. *Anoplia* is internally provided with two divergent septa in the brachial valve, a condition quite unlike the interior of *Chonetinetes*. *Anopliopsis*, although provided with radial rows of platelike septa, has a small cardinal process in contrast to the rather massive one of *Chonetinetes*.

*Chonetinetes* is most like *Chonetina* in external details, but differs in having a much more modest development of the fold and sulcus, and, furthermore, does not have the platelike septa of the brachial valve described and illustrated for *Chonetina*; also, it is supplied with a conspicuous median septum not found in *Chonetina*, according to Muir-Wood (1962:57). Although the anterolateral cones in the visceral region of *Chonetinetes* have strongly aligned taleolae or endospines on them that suggest septation, the spines are, nevertheless, discrete and do not form septa in any of the species from the Glass Mountains or the Guadalupe Mountains.

DISCUSSION.—Three species of this interesting little genus are now known, two from the Glass Mountains and one from the Guadalupe Mountains. The distinctive specific feature of the type species is the obsolescence of the fold and sulcus at the anterior of the shell. The other two species do not attain the size of *C. reversus* and therefore do not have the fold and sulcus obliterated at the anterior. A feature of interest in the pedicle valve is the large size and strength of the pseudodeltidium, which is unusually long and highly arched for a chonetid. It is welded to the apex by a thick plug of adventitious shell that fills the apex and in some specimens protrudes anterior to the front of the pseudodeltidium.

The highest part of the median septum is rooted in this plug.

The most unusual structure of this rare genus is the cardinal process, which is exceptionally large for so small a shell. When viewed from the posterior side, where it is usually completely visible because of rotation of the brachial valve interarea, it is essentially an equilateral triangle, with the distal apex covered by a chilidium. In some specimens the apical part of the chilidium is missing and the sides of the cardinal process are partly covered by childial plates. The myophore of the cardinal process bears four ridges, the median two close together and narrowly protrude beyond the distal side of the triangle. The process is thus distinctly trilobed in this view. The antron is deep; its sides are narrow and buttress the lateral extremities of the cardinal process.

The adductor field and the dividing brevisseptum occupy the flattened region anterior to the antron. No specimen was seen in which the antron is filled with adventitious shell. Anterior to the brevisseptum a deep trough divides the subconical anterolateral areas of the visceral disc. The anderidia are erratically developed, fairly strong and protruding in some specimens, but not visible in others. No markings were seen that could be construed to be the so-called brachial ridges, and no pallial trunks were individualized.

### *Chonetinetes angustisulcatus*, new species

PLATE 477: FIGURES 1–28

Small, strongly concavo-convex, generally wider than long, subrectangular in outline, greatest width at hinge; cardinal extremities acute with angle varying from about 65° to 80°. Sides strongly to slightly oblique; anterior margin subtruncate to slightly rounded. Anterior commissure with slight and narrow fold in dorsal direction. Posterior margin with four to six short, oblique spines on each side.

Pedicle valve with gently convex lateral profile, umbonal region narrowly curved; anterior profile strongly domed and with steeply sloping sides. Median and umbonal regions strongly swollen; umbonal slopes steep. Sulcus variable, originating on umbo and extending anteriorly to front margin

as narrow, slightly expanding depression. Sulcus usually present at anterior margin but variably developed. Ears small, well demarcated, strongest, most acute and most extended in young, but becoming stouter and less acute in adults. Pseudodeltidium short and narrowly rounded.

Brachial valve strongly concave, maximum depth just anterior to umbonal region, becoming shallower anteriorly. Cardinal extremities flattened and demarcated by short, steep lateral slope; anterior slope shallow. Fold originating posterior to midvalve near umbonal region, low, narrow, inconspicuous, usually not defined at anterior. Interarea shorter than that of pedicle valve, strongly hypercline.

Pedicle valve interior with small teeth and moderately thick apical callosity; median septum

short and low, not serrated; median ridge extending anterior to septum to beyond midvalve, and in some specimens marked by moderately long spines. Lateral and anterior slopes of inner wall strongly granulose and spinose in some.

Brachial valve interior with moderately large cardinal process covered at apex by chilidium; cardinal process moderately excavated. Prosocket ridges moderately oblique, narrow and defining small sockets. Adductor dividing ridges generally delicate, only slightly elevated and not conspicuous. Median septum generally thick, not strongly elevated. Median depression separating anterolateral extremities of visceral region moderately deep; visceral region moderately thickened except in extreme cases of old age; visceral region strongly granulose.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 721j							
151815a	6.1	4.9	9.3	7.1	6.9	3.1	1.7
(holotype)							
151815b	5.0	4.5	8.0	8.0*	6.5	2.9	1.5
151815c	5.1	4.3	7.5	7.4	6.7	2.8	1.8
151815d	4.7	3.8	7.0	5.8	5.3	2.5	1.5
151815e	3.9	3.1	5.5	5.8	4.8	2.3	1.2
151815f	4.6	4.0	7.0	6.8	5.9	2.2	1.2
151815g	3.7	3.0	5.0	5.7	4.3	2.0	0.9

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 703, 703a, 720d, 721j, 721x, 721z, 722e, 724c, 726d.

DIAGNOSIS.—*Chonetinetes* with narrow sulcus and thin, low fold reaching anterior margin.

TYPES.—Holotype: USNM 151815a. Figured paratypes: USNM 151815c, h, i, 153676a-d. Measured paratypes: USNM 151815b-g. Unfigured paratypes: USNM 151815b, d-g.

COMPARISONS.—This species is smaller and more transverse than *C. varians*, from approximately the same horizon, and is readily distinguished from it by the fact that the sulcus is shallow and narrow and extends to the anterior margin. In the latter respect *C. angustisulcatus* resembles the Guadalupe species but the pedicle valve is less inflated, and the sulcus

is shallower and narrower. Furthermore, details of the interior of the latter two are different: the brachial valve of *C. varians* has a stronger median ridge and the anterior slope is longer. In the pedicle valve of *C. varians* the septum is more strongly developed than in *C. angustisulcatus*.

This species is readily distinguished from *C. reversus* Cooper and Grant. Although it comes from the same formation as the latter, it is from a different level. It was taken from the top of the Road Canyon Formation northwest of the Hess Ranch.

DISCUSSION.—The young of *C. angustisulcatus* are fairly strongly transverse and have well-extended ears. This is true of *C. varians* but the young of that species are less transverse. With growth *C. angustisulcatus* lengthens the shell and the ears become

less acute, so that the fully adult shell approaches a squarish outline, like those adults of the other two species.

The interior of *C. angustisulcatus* is variable depending on the degree of calcification of the shell. One pedicle valve has fairly strong spines on the sides and anterior of the diductor scars. These may be caused by strong calcification, or an alternative explanation may be the differential solution on the surface of the interior which, in a thick-shelled form, has dissolved away fibrous shell faster than the taleolae and has left these in exaggerated relief. Pitting on the interarea of this specimen (USNM 151815i) lends strength to the latter hypothesis. On the other hand, the chonetids at this stratigraphic level at USNM 707e, and 703d are strongly spinose internally.

*Chonetinetes reversus* Cooper and Grant

PLATE 477: FIGURES 29-48

*Chonetinetes reversus* Cooper and Grant, 1969:4, pl. 3: figs. 1-7.

Small, strongly concavo-convex, outline variable, subquadrate to rectangular, midwidth and length varying from approximately slightly wider to equal; hinge widest part, cardinal extremities produced into small ears; sides strongly oblique in young but slightly rounded in adults. Anterior margin narrowly rounded to truncate. Anterior commissure with broad fold toward pedicle valve in adults. Posterior margin with four oblique spines on each side. Surface smooth.

Pedicle valve unevenly convex in lateral profile, umbonal region narrowly rounded but anterior two-thirds moderately convex; anterior profile a

narrow dome, sulcate on crest. Beak small, hanging over interarea; umbonal region strongly swollen, slopes steep; median region strongly swollen; sulcus originating on umbo but extending only to midvalve in adults; flanks bounding sulcus narrowly rounded and steep-sided. Anterior half narrowly swollen and with steep lateral slopes. Ears small, not well demarcated but acutely pointed in some specimens to form angle of 60° to 70°. Interarea curved, fairly long, apsacline.

Brachial valve deeply concave, maximum depth near midvalve; ears somewhat flattened and demarcated by indistinct oblique fold; sides steeply sloping medially but anterior forming shallow trough. Fold low, narrowly rounded, confined to about midvalve, not extending to anterior margin or to umbo. Interarea fairly long but shorter than on pedicle valve, strongly hypercline.

Pedicle valve interior with thick apical callosity and strongly elevated but short median septum; median ridge moderately elevated at midvalve and marked by row of taleolae; inner lateral slopes strongly pustulose.

Brachial valve interior with wide flat cardinal process having median two ridges produced into narrow lobe; prosocket ridges extended laterally to lateral margins of visceral region; adductor dividing ridges not developed, but anderidia well formed, flattened, and free at distal extremities; brevisseptum short and low; midvalve forming deep trough bounded by strongly papillose lateral areas.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 707e, 710h, 710i, 712q, 721j.

DIAGNOSIS.—*Chonetinetes* with fold and sulcus not reaching the anterior margin in adults.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 710h							
151810a	8.3	7.3	12.0	12.4*	8.1	4.3	2.5
151810b	7.6	6.9	10.0	11.0	8.2	3.9	2.1
151810c	8.4	7.3	11.5	10.0	8.7	4.7	3.2
151810d	7.1	6.5	10.0	11.4	8.8	4.7	2.4
151810e	5.3	5.0	6.5	7.5	6.0	2.5	1.0
153193a	9.0	6.9	13.0	13.2	10.0	5.0	3.1
(holotype)							

Types.—Holotype: USNM 153193a. Figured paratypes: USNM 153193b-d, f, k, l. Unfigured, measured hypotypes: USNM 151810a-e. Unfigured paratypes: USNM 153193e, g-j.

Comparisons.—This species is distinguished from *Chonetinetes varians*, new species, in attaining a much larger size and in having the sulcus confined to the posterior half of the pedicle valve and the fold to the median portion of the brachial valve. In adults neither of these features appears at the front margin.

Discussion.—The internal structure of these shells is characteristic of that of Upper Paleozoic chonetids. In the pedicle valve the teeth are short and wide, the interarea long for such small shells, and the pseudodeltidium strongly elevated and fairly long. The septal portion of the median ridge is short and confined to the deepest part of the valve and its front edge is serrated to somewhat spinose. The sloping inner surface of the sides is strongly granulose to moderately spinose.

The cardinal process of the brachial valve is fairly well elevated and is deeply excavated anteriorly. Its apical part is apparently not covered by a chilidium. The prosocket ridges are widely extended and bound wide sockets. The adductor dividing ridges are flat, well elevated, and extended anteriorly. On the anterior side of the inner adductor pair several small spines protrude near the muscle scar edge. The median septum is not strongly developed and does not extend beyond midvalve. It is located in the deep groove bounded by the swollen anterolateral extremity of the visceral region. This swollen portion is strongly granulose and merges into the long and steep anterior slope.

This species occurs chiefly in the upper part of the Road Canyon Formation, but is abundant only

at USNM 710h, where it occurs in bituminous limestone, being usually well scattered and having a range of about 30 feet vertically.

*Chonetinetes varians*, new species

PLATE 477: FIGURES 49–77; PLATE 478: FIGURES 1–12; PLATE 502: FIGURE 63

Small, subtrapezoidal in outline, maximum width at hinge; cardinal extremities extended into acute points having angle of 65° to 75°. Sides concave; anterolateral extremities narrowly rounded; anterior margin indented medially. Anterior commissure with narrow fold dorsally. Posterior margin with six or seven oblique spines on each side.

Pedicle valve with uneven convex lateral profile, maximum convexity at or slightly posterior to middle and anterior somewhat flattened. Anterior profile is narrow dome with precipitous sides and deep median indentation. Umbonal region swollen and protruding slightly posterior to posterior margin; median region strongly swollen. Sulcus usually deep and narrow, originating on umbo and indenting anterior margin, but somewhat variable. Flanks bounding sulcus forming narrow plications with steep lateral slopes and anterior slope not as steep as lateral ones. Posterolateral extremities strongly depressed below midvalve, narrowly but moderately rounded. Interarea short, orthocline to anacline.

Brachial valve with deep medial depression bounded posterolaterally by strong folds separating posterolateral extremities from midvalve and moderately steep anterolateral and anterior slopes. Fold generally strong, commonly narrow, originating slightly posterior to midvalve and prominent an-

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
AMNH 635							
151820	5.6	4.8	7.5	8.2	6.5	3.0	1.8
USNM 731							
151817a	5.3	4.8	7.5	8.2	6.0	2.7	0.9
151817b	5.5	5.0	7.5	8.6	5.5	3.2	0.9
151817c	6.4	5.0	10.5	10.0	6.9	3.5	1.0
USNM 732a							
153677a	7.1	5.6	9.5	11.3	8.4	3.5	1.2
(holotype)							

teriorly. Posterolateral extremities flattened and with precipitous slopes toward midvalve. Lateral commissure strongly folded in dorsal direction.

Pedicle valve interior with apex thickly plugged by callus; median septum short, not strongly elevated; median ridge anterior to septum greatly reduced, formed by strong exterior sulcus. Lateral slopes strongly granulose.

Brachial valve interior with large and deeply excavated cardinal process; prosocket ridges long; adductor dividing ridges variable, fairly strong in some specimens, weak in others; anderidia visible in some specimens. Brevisseptum well developed at anterior, lying in deep depression produced by exterior fold, serrate but not reaching antron. Lateral and anterolateral parts of visceral region narrowly thickened and spinose.

STRATIGRAPHIC OCCURRENCE.—Bell Canyon Formation (Hegler, Pinery, and Rader members).

LOCALITIES.—Hegler: AMNH 404, 524, 635; USNM 731, 732a, 740d. Pinery: AMNH 33, 398. Rader: AMNH 410; USNM 725f, 740a, 740j.

DIAGNOSIS.—Small, moderately convex *Chonetinetes* having a strong sulcus in the pedicle valve that reaches the anterior margin and the brachial fold present, but not conspicuous, at the anterior.

TYPES.—Holotype: USNM 153677a. Figured paratypes: USNM 151817a, c, e, f; 153677b; 153678a, b; 153679; 153680a-d. Measured paratypes: USNM 151817a-c; 151820. Unfigured paratypes: USNM 151817b, d.

COMPARISON.—This species differs conspicuously from *Chonetinetes reversus* Cooper and Grant, of the Glass Mountains, in having the sulcus and fold extended to the anterior margin. It also differs in being generally a much smaller and more thin-shelled species.

DISCUSSION.—The exterior of *Chonetinetes varians* is smooth but some specimens, when abraded or weathered, exhibit coarse radial lines. These are conspicuous in specimens from AMNH 635 but do not appear in specimens from USNM 731 which is at the same stratigraphic level about 1.25 miles to the north. Radial lines on abraded shells appear in some of the other smooth chonetids such as *Dyoros* Stehli.

As might be expected the interiors of *C. varians* are different in detail from those of the Glass Mountains species. The median septum is not strongly developed and is not serrated on the edge.

The inner slopes are strongly granulose, and exceptionally coarse granules appear in some specimens along the anterior part of the ridge formed by the median sulcus.

Inside the brachial valve the median septum is generally extended beyond midvalve for a short distance and the anterior end is free and extended. The visceral region is not deeply divided medianly and is not strongly thickened anterolaterally but is strongly granulose.

This species is rare at the localities from which it was taken. Too little is known of the brachiopods of the Guadalupe region to be able to say whether it is or is not a rare shell throughout the area.

### UNDULELLINAE, new subfamily

Small, transverse, smooth, Rugosochonetidae having broad sulcus on pedicle valve and broad, poorly formed fold on brachial valve. Spines nearly vertical to posterior margin. Brachial valve interior with anteromedian depressed area bounded on posterior margins by curved transverse ridge and short median septum scarcely reaching midvalve.

Texas genera: *Undulella* and *Micraphelia*, both Cooper and Grant, 1969.

*Undulella* is most characteristic of the lower Guadalupian. It is abundant in the upper part of the Willis Ranch Member of the Word Formation but uncommon in the lower part of that member and rare in the other two members. It is uncommon in the Cherry Canyon Formation (Getaway Member). It occurs in the lower part of the Road Canyon Formation but is very rare there. *Micraphelia*, abundant in the Bell Canyon members, has a brachial interior like that of *Undulella* but its anterior margin is not broadly folded.

### Genus *Undulella* Cooper and Grant, 1969

*Undulella* Cooper and Grant, 1969:5.

Small, somewhat rectangular in outline, hinge and midwidth nearly equal. Cardinal extremities nearly right angle. Valves concavo-convex; ears not demarcated. Anterior commissure with broad fold toward brachial valve. Surface smooth, except for concentric lines of growth. Spines moderately long, nearly at right angle to posterior margin.



Pedicle valve with short pseudodeltidium and short interarea; teeth large; median septum well defined apically, not well developed anteriorly as ridge, but when so developed, not reaching to midvalve. Muscle field subflabellate. Visceral region narrowly confined by submarginal fold or valve swelling.

Cardinal process small, deeply excavated anteriorly in young, antron partly filled in adults; outer socket ridges strong; prosocket ridges thick but short. Adductor dividing ridges not developed; anterior tips of anteridia usually visible; brevisseptum short with distal end slender but proximal part strongly thickened to form rounded ridge extending to antron. Anteromedian part of visceral area occupied by deep pit bounded posteriorly by two thick ridges extending laterally from distal unthickened part of brevisseptum and anteriorly by transverse swelling inside valve margin.

TYPE-SPECIES.—*Undulella undulata* Cooper and Grant (1969:5, pl. 2: figs. 1–7).

DIAGNOSIS.—Smooth Chonetidina with a broad median sulcus in the pedicle valve and brachial valve visceral region anteriorly deepened and modified.

COMPARISONS.—The exterior form of this little genus is quite distinctive, with its broad dorsal deflection of the anterior part of both valves to form a broad and gentle fold and sulcus. Externally it suggests *Leurosina*, new genus, in its broad anterior deflection but it differs in the nature of the posterior spines and the greater strength of the dorsal anterior deflection. Furthermore, the interior details of the brachial valve are different from those of *Leurosina* in the manner of thickening and the part thickened.

*Dyros* (*Dyros*), or the other subgenera of that genus, will not be confused with *Undulella* because of their usually strong fold and sulcus and extended hinge. The same is true of *Sulcataria* Cooper and Grant, which resembles *Undulella* in general form. *Chonetinetes* and *Quadrochonetes* Stehli cause no confusion because of their unusual exterior characters. *Tornquistia* Paeckelmann, with its two divergent septa inside the brachial valve cannot be confused although the exteriors are similar.

DISCUSSION.—The surface of this genus is smooth, like *Lissochonetes* and some other genera. It is, however, more gently folded than most of these, and lacks pronounced ears. Generally the hinge is

about equal to the midwidth, in some specimens exceeding it slightly, but in others definitely less than the midwidth. When the hinge is wider than the midwidth, the cardinal extremities are angular. The anterior margin is broadly rounded but the anterior commissure has a broad dorsal fold, and this tends to flatten the margin. The interarea and pseudodeltidium are like those features in other Permian chonetids.

The posterior spines of *Undulella* are unusual in extending at a right angle to the posterior margin, or in some specimens leaning medially. The spines are moderately long, very slender, and taper distally.

The exterior of the brachial valve is unusual in its lack of ears and the broad gentle concavity. In auriculate genera the ears are set off by oblique ridges that bound the deepest part of the valve, but in *Undulella* no such ridges exist; the valve is fairly evenly and gently concave. The chilidium is developed like that of other Permian chonetids. Although the exterior of this genus is unusual and distinctive, the more significant generic characters appear inside both valves.

Inside the pedicle valve, the tooth is an oblique flat plate tilted anterolaterally so that the outer layer of the palintrope hangs over the lateral sloping edge of the tooth to form a shallow socket that receives the prosocket ridge of the opposite valve. The inner face of the tooth slopes to a ridge at its base, near the junction with the floor. This ridge defines the edge of the fossette that locks with the prosocket ridge of the brachial valve.

The apex of *Undulella* is filled with callus that helps to fix the pseudodeltidium. The short median septum generally is buried in this callus, or is greatly thickened by it. The septum is not continued forward to any great extent, but a thick ridge, not extending as far as midvalve, commonly divides the posterior end of the muscle field. The muscle scars are not clearly impressed in any specimen, but those that can be individualized appear to be like those of *Dyros* (*Dyros*) the commonest Texas chonetid.

Many of the pedicle valves of *Undulella* have the visceral region deepened and confined to midvalve. The lateral and anterior regions become somewhat swollen around the visceral region, and coarse pustules, on the edge of the slope into the deepened visceral region, help to emphasize this. Many pedicle interiors appear to have a flattened or

somewhat swollen band around the deeper central region, which usually is widely elliptical. This deepening of the visceral region undoubtedly is an accommodation to the unusual thickening of the visceral region of the opposite valve.

The cardinal process of the brachial valve normally is bilobed, but the lobes are closely pressed together, and the four ridges on the posterior face are compressed. The median portion is somewhat produced, and hangs over the antron. The chidium covers the dorsal half of the cardinal process. Articulation is like that of *Dyoros* (*Dyoros*), the prosocket ridges are thick, but not elongated.

The brevisseptum extends to about midvalve, where it is slender at the distal end. Posteriorly, this is thickened and extended to the antron. In some specimens this part of the valve is greatly thickened, the socket plates and cardinal process joining with it by callus deposit to form ridges having the general form of an inverted anchor. The adductor scars in this genus are separated widely, the inner pair being small and located on either side of the thickened brevisseptum just anterior to the thickening on the anterior side of the antron. These scars are sunk deeply into adventitious shell, and the outer scars form large patches just anterior to the socket ridges. The adductor dividing ridges normally are not developed, but the anderidia at the posterior ends of these appear as two small rodlike processes protruding from the valve floor on

each side of the inner pair of adductor scars. Just anterior to these scars, two thick ridges that extend laterally or slightly anterolaterally divide the adductor scars from the anterior part of the shell. In front of these ridges is a subcircular depression, bounded anteriorly by a transverse curved ridge, marking the edge of the visceral disc and the anterior slope to the margin. The anterior and posterior transverse ridges bound an anteromedian depressed area that occupies a fair part of the visceral region. In many specimens two additional ridges, usually in the form of rows of thick taleolae, extend slightly anteriorly from each side of the end of the brevisseptum in a direction slightly anterolateral to the anterior rim. These ridges are variously developed, strong in some specimens but lacking from others. Possibly the ridges extending anterolaterally from the anterior side of the adductors are a modification of the adductor dividing ridges.

### *Undulella guadalupensis*, new species

PLATE 492: FIGURES 2-13

Usual size for genus, wider than long, and subrectangular in outline; hinge equal to or slightly less than midwidth. Cardinal extremities generally obtuse or faintly acute; sides nearly straight to well rounded. Anterior margin broadly rounded to

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
AMNH 600							
152078a	6.7	5.8	8.0	9.2	9.7	2.1	1.5
152078b	7.4	?	9.0	10.4	11.2	2.3	?
152078c	7.4	?	9.0	10.5	11.8	2.3	?
152078d	6.8	?	8.0	8.4	9.9	1.9	?
152078e	6.9	?	8.5	9.4	10.2	2.1	?
152078f	6.3	5.9	7.0	7.8	9.2	1.8	1.2
152078g	5.4	5.0	6.5	6.9	7.8	1.6	1.0
USNM 730							
152076	6.3	5.9	7.0	9.0	10.0	1.9	1.3
USNM 732							
152077a	8.0	7.2	10.0	9.8	11.8	2.8	1.7
(holotype)							
152077b	6.9	?	8.5	10.6	10.8	2.1	?
152077c	6.6	?	8.0	9.2	10.5	1.9	?
152077d	5.9	?	6.0	7.9	9.3	2.0	?
152077e	6.1	?	6.5	9.1	9.4	1.8	?

subtruncate. Interarea short in both valves. Posterior margin with 5 or 6 spines on each side.

Pedicle valve moderately convex in lateral profile, maximum convexity at midvalve, but anterior half less convex than posterior half; anterior profile a broad dome with long moderately sloping sides. Beak and umbo small; umbo narrowly swollen. Median region somewhat inflated; sulcus originating just posterior to midvalve, wide and bounded by broadly but sharply convex flanks. Sulcus occupying more than half valve width. Lateral and posterolateral slopes long and moderately steep.

Brachial valve moderately concave, most concave in posteromedian region; fold originating near midvalve and deflecting much of anterior half in dorsal direction. Lateral troughs bounding fold shallow; posterolateral regions flattened, not demarcated as ears.

Pedicle valve interior with small teeth and modest apical callosity. Median septum short and inconspicuous; ridge anterior to median septum not reaching midvalve, low and delicate. Muscle scars slightly impressed. Lateral margins flattened to form finely granulose band; inner slopes granulose.

Brachial valve interior with small excavated process and narrow widely divergent prosocket ridges. Adductor dividing ridges fairly strong; adductoria not well developed. Shell moderately thickened anterior to adductor field and visceral region thickened anterolaterally. Anterior and sides with flattened granulose marginal rim.

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member).

LOCALITIES.—AMNH 496, 600; USNM 730, 732.

DIAGNOSIS.—*Undulella* with hinge generally markedly narrower than midwidth.

TYPES.—Holotype: USNM 152077a. Figured paratypes: USNM 152077b, c, f; 152076; 152078a, b, d. Measured paratypes: USNM 152076, 152077b-e, 152078a-g. Unfigured paratypes: USNM 152077d, e; 152078c, e-g.

COMPARISONS.—This species is most like *U. undulata* Cooper and Grant, but differs in the proportions of its shell and other features. The hinge of *U. guadalupensis* is usually considerably narrower than midwidth, whereas that of *U. undulata* is only slightly less wide than the midwidth. The fold of the brachial valve is usually elevated more than that of the Glass Mountains species and the sulcus is consequently deeper.

DISCUSSION.—This is a rare species at every locality where it has been found. It adds little morphological detail to the genus because the brachial valves are not strongly thickened. They are, however, typical of the genus.

### *Undulella matutina*, new species

PLATE 502: FIGURES 34-43

Small for genus, transversely rectangular in outline, hinge generally narrower or nearly equal to midwidth; sides usually nearly straight or rounded; cardinal extremities usually lightly obtuse; anterior margin broadly rounded; interarea short in both valves; posterior margin with 2 (?) spines on each side of beak.

Pedicle valve gently convex in anterior profile, forming broad, low, even dome in anterior profile; approximately anterior third geniculated in anterior direction to form broad poorly defined sulcus. Beak scarcely defined, posterior half to two-thirds gently swollen; lateral anterior slopes short, moderately steep.

Brachial valve nearly flat in posterior two-thirds but bent moderately in dorsal direction in anterior third, line of geniculation forming slight concavity; slight oblique shallows marking off indistinct ears.

Pedicle valve with interior deep cavity marked laterally by flattened area; teeth moderately thick, oblique; median septum defined only in posterior delthyrial region; no anterior ridge; muscle marks not defined.

Brachial valve interior with thick cardinal process having small antron; median ridge thick but low; crescent-shaped ridges bounding anterior depression thick and endospinose.

MEASUREMENTS (in mm).—From locality USNM 732j, specimens 153749a (holotype) and d, respectively: length 6.0, 5.2; brachial valve length 5.3, 4.6; surface length 7.0, 6.5; hinge width 8.9, 7.5?, midwidth 9.2, 8.0; height 2.0, 1.8; thickness 1.5, 1.4.

STRATIGRAPHIC OCCURRENCE.—Road Canyon Formation.

LOCALITIES.—USNM 721j, 732j, 736x.

DIAGNOSIS.—Small *Undulella*, generally with the midwidth wider than the hinge width and moderately geniculated anteriorly.

TYPES.—Holotype: USNM 153749a. Figured paratypes: USNM 153749b, c. Measured and unfigured paratype: USNM 153749d.

COMPARISON.—This species has a thick shell, differing in this respect from *U. guadalupensis*, new species, but it does not attain the length or size of the largest specimens of that species. It is similar to young specimens of *U. undulata* Cooper and Grant but is thicker-shelled, less strongly geniculated and does not attain the width of adults of the Willis Ranch species. The Road Canyon species is of particular interest because it is the earliest one known, but it is extremely rare.

*Undulella undulata* Cooper and Grant

PLATE 492: FIGURES 14–32

*Undulella undulata* Cooper and Grant, 1969:5, pl. figs. 1–7.

Small, transversely rectangular, hinge varying from slightly less to slightly more than midwidth; sides generally gently rounded; anterolateral extremities strongly rounded; anterior margin broadly rounded to truncate. Cardinal extremities not

auriculate, nearly forming right angle. Anterior commissure with broad dorsal fold. Surface smooth. Posterior margin with four erect spines on each side, at right angles to posterior margin; spines attain length of 2.5 mm.

Pedicle valve unevenly convex in lateral profile, posterior half flatly convex but anterior half strongly bent in gentle curve toward brachial valve. Anterior profile nearly flat but with slight median curve. Beak small; umbo slightly swollen. Mid-region slightly swollen and descending gently to cardinal extremities. Sulcus broad and shallow, originating at midvalve. Flanks bounding sulcus oblique and slightly convex. Interarea moderately long, apsacline. Pseudodeltidium strongly convex.

Brachial valve gently concave, most concave at midvalve; anterior median half gently curved in dorsal direction, with flanks forming anterolateral extremities somewhat depressed relative to midvalve and to cardinal extremities. Interarea short, hypercline. Cardinal extremities flattened.

Interior as described under discussion of genus.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 706e							
152070a	7.1	6.5	8.5	12.4	12.3	2.4	1.8
152070b	7.1	6.2	8.5	12.2	12.0	2.3	1.7
(holotype)							
152070c	6.9	6.5	7.5	12.0	11.6	2.4	1.7
152070d	6.4	5.9	7.0	10.6	10.9	2.2	1.8
152070e	7.2	6.7	8.5	12.2	12.0	2.1	1.4
152070f	6.6	6.2	7.0	10.1	10.4	2.1	1.6
152070g	6.4	6.0	7.0	11.3	11.0	2.0	1.2
152070h	6.5	6.3	7.0	11.2	10.9	1.8	1.2
152070i	5.1	4.8	6.0	8.0	7.7	1.4	1.0
152070j	4.5	4.4	5.0	7.4	6.9	1.2	0.8
152070k	6.6	6.0	7.5	11.4	11.4	1.9	1.3
USNM 706							
152066a	7.3	6.6	8.5	11.6	11.2	2.0	1.3
152066b	6.0	5.6	6.5	9.4	9.6	1.7	1.0
152066c	6.8	6.0	7.5	11.4	11.4	2.1	1.4
152066d	6.9	6.5	8.0	10.8	11.6	2.7	2.3
152066e	5.0	4.6	5.5	7.3	7.7	1.4	0.7

STRATIGRAPHIC OCCURRENCE.—Word Formation (China Tank, Willis Ranch members, and lens just above the last).

LOCALITIES.—China Tank: USNM 706c. Willis

Ranch: AMNH 505; USNM 706, 706e, 724u, 735c. Lens: 706b.

DIAGNOSIS.—*Undulella* with broad sulcus and tendency of cardinal extremities to become acute.

**TYPES.**—Holotype: USNM 152070b. Figured paratypes: USNM 152070h, g, l-s; 153186a, b. Measured paratypes: USNM 152066a-e; 152070a, c-k. Unfigured paratypes: USNM 152070a, c-g, i-k. Figured hypotypes: USNM 152069, 153723a-c.

**COMPARISON.**—This species has been compared to *U. matutina* and *U. guadalupensis*, both new, under those headings. Generally these two can be distinguished from *U. undulata* by the wider hinge, acute cardinal extremities, and broader sulcus.

### Genus *Micraphelia* Cooper and Grant, 1969

*Micraphelia* Cooper and Grant, 1969:4.

Small, semielliptical to subrectangular; hinge usually widest part but frequently slightly narrower than midwidth; ears not well formed; moderately to strongly concavo-convex; anterior commissure unfolded; surface smooth and posterior margin with small oblique spines.

Pedicle valve interior with moderately large teeth and thick apical callosity. Median septum short; ridge anterior to septum variously developed, usually moderately thick and reaching midvalve. Flattened lateral margins and inner slopes granulose.

Brachial valve interior with large deeply excavated cardinal process and moderately wide, slender prosocket ridges defining slitlike sockets; adductor dividing ridges scarcely developed but antheridia delicate and protruding. Brevisseptum moderately strong and thick, extended posterior to antron in old shells. Anterolateral loops of visceral region thickened and spinose.

**TYPE-SPECIES.**—*Micraphelia scitula* Cooper and Grant (1969:4, pl. 5: figs. 10–12).

**DIAGNOSIS.**—Small unfolded, narrow-hinged Chonetacea with thickened and spinose anterolateral visceral region.

**COMPARISONS.**—The small size of the members of this genus make comparison necessary with a few genera only. The genus is most like *Tornquistia* Paeckelmann in exterior details and probably could not be distinguished from that genus on this basis. The brachial valve interior of *Tornquistia*, however, has two divergent lamellae in the median region, entirely unlike *Micraphelia*. Another genus suggestive of this one is *Chonetina* Krotov but that has a prominent sulcus on the pedicle valve and a fold on the brachial valve.

**DISCUSSION.**—The interior details of this genus are like those of the family, but the small size and lack of folding make it unique. The most interesting feature is the development of the visceral region in the brachial valve. Young specimens show very little thickening of the anterolateral part of this region but the entire interior is strongly granulose. In older shells, thickening and spinosity develop from a point anterior to the distal end of the prosocket ridge and curve to the anterolateral extremity of the visceral region, thickening the valve in passage. At the extremity it forms an angular loop and extends posteromedially to end just anterior to the adductor field. This ascending branch bounds the median trough, but this is only moderately deep. In a few specimens the anterolateral visceral region is greatly thickened and in one case the curved ridges are rather coarsely granulose or spinose. In the type species of the genus an additional row of spines extends anterolaterally within the confines of the visceral ridges.

This genus is most abundant in the limestones of the Bell Canyon Formation. Specimens suggesting it occur in the Capitan Limestone but they are not sufficiently abundant to make satisfactory comparison with the two species of *Micraphelia*. It is possible that "*Chonetes*" *permiana* Shumard belongs in this genus, perhaps to one of the two species defined below, but it is impossible to be sure.

### *Micraphelia* cf. "*Chonetes*" *permiana* Shumard

*Chonetes permiana* Shumard, 1860:390.

In view of the uncertainty attending identification and location of this species, and the fact that the types have been irretrievably lost, it is best to abandon the species. Shumard states that his species is a small one but that its ears are mucronate. Girty (1909:227) considers this fact but remarks that his specimens agree with Shumard's so closely in all other respects that they must be the same. R. E. King (1931:62) mentions that the specimens he assigns to the species have the cardinal extremities nearly at right angles but his figures showing the outlines restored have distinctly acute ears. The latter specimens strongly suggest *Dyoros* (*Lissosia*) *parvus*, new species, a poorly sulcate species quite unlike any specimens referred by Girty to Shumard's species.

The specimens figured by Girty as *Chonetes*



*permanus* are here referred to *Micraphelia scitula* Cooper and Grant (1969).

*Micraphelia pumilis*, new species

PLATE 493: FIGURES 1-10

Small, moderately concavo-convex, wider than long, wide hinge usually equal to or slightly less than midwidth. Cardinal extremities ranging from slightly acute to slightly obtuse, usually nearly right angle. Sides nearly straight to gently rounded; anterior margin broadly rounded. Anterior commissure unfolded. Surface smooth but with concentric lines and plaits of growth. Posterior margin with four spines on each side of beak.

Pedicle valve with moderate and even convexity in lateral profile, maximum curvature at midvalve. Umbonal region somewhat narrowly swollen; median region moderately inflated and with moderately steep slopes to lateral and anterior margins. Sulcus absent. Interarea short, orthocline to anacline.

Brachial valve with gentle and fairly even concavity, deepest part at midvalve, lateral and

anterior margins sloping moderately toward midvalve. Cardinal extremities slightly flattened, not demarcated as ears.

Pedicle valve interior with stout and thick teeth having deep fossettes; apical callosity filling apex, and with thick but short median septum continued anteriorly to near anterior end of muscle field. Posterolateral regions somewhat flattened and forming finely granulose border around inner margin; lateral slopes strongly granulose.

Brachial valve interior with small, depressed, excavate cardinal process; prosocket ridges short and thick; adductor dividing ridges indistinct but in some species buried under adventitious shell; anderidia seen only in young, buried in adults. Brevisseptum slender anteriorly but greatly thickened posteriorly and extending to antron. Brevisseptum flanked by four ridges of which two are thick, spinose swellings near midvalve and directed anterolaterally, two other ridges bounding anterior part of brevisseptum and extending anteriorly for short distance. Anterior margin of visceral region swollen and spinose, with deep anteromedian trough between two sides in old specimens.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
AMNH 46							
152073a	6.3	5.6	8.0	9.0	9.0	2.2	1.6
(holotype)							
152073b	6.5	5.5	8.0	8.6	8.8	2.2	1.9
152073c	6.1	5.4	7.5	8.7	8.7	2.0	1.4
152073d	5.9	4.9	7.0	8.0	7.7	2.2	1.6
152073e	5.6	4.9	6.5	7.8	7.8	2.0	1.6
152073f	6.0	5.0	7.0	8.2	8.6	2.2	1.7
152073g	6.9	6.0	8.5	9.0	9.1	2.5	2.1
152073h	3.4	2.6	3.5?	4.4	4.4	?	?
152073i	4.3	4.0	4.5	6.7	6.3	1.3	1.0
152073j	4.8	4.2	5.5	7.2	7.2	1.4	1.3
152073k	4.0	3.5	4.5	5.0	5.5	1.4	1.1

STRATIGRAPHIC OCCURRENCE.—Bone Spring Formation.

LOCALITY.—AMNH 46.

DIAGNOSIS.—Small *Micraphelia* with hinge and midwidth about equal and the brachial valve only slightly deflected in a dorsal direction.

TYPES.—Holotype: USNM 152073a. Figured

paratypes: USNM 152073b, c; 153724a-f. Measured paratypes: USNM 152073b-k. Unfigured paratypes: USNM 152073d-k.

COMPARISONS.—This species need not be compared directly with either of the other two known species because both of them are transverse, with variable hinges, and both have the brachial valve

fairly strongly deflected in a dorsad direction. Furthermore, both of them have a fairly well-defined sulcus in the pedicle valve.

DISCUSSION.—This species deviates from the usual in this genus in the slight folding of the brachial valve. Young specimens and some adults exhibit scarcely any anterior folding. The generic characters are mainly in the manner of thickening of the structures of the brachial valve.

*Micraphelia scitula* Cooper and Grant

PLATE 493: FIGURES 11–23

*Chonetes permianus* Girty (not Shumard), 1909:226, pl. 20: figs. 1–3, pl. 29: figs. 1, 2.  
*Micraphelia scitula* Cooper and Grant, 1969:4, pl. 5: figs. 10–12.

Small, transversely subrectangular in outline, width greater than length, hinge approximately equal to midwidth, shorter in some specimens but slightly longer in others. Sides nearly straight to gently rounded; anterior margin broadly rounded; convexity somewhat variable. Anterior commissure unfolded. Posterior margin with four (?) oblique spines on each side.

Pedicle valve fairly evenly and moderately convex in lateral profile, maximum convexity near midvalve; anterior profile forming broad dome with long sloping sides. Umbonal region swollen and merging into strongly inflated median region; umbonal slopes to cardinal extremities moderately steep; lateral slopes steep, but anterior slope steeper than lateral ones. No sulcus. Cardinal extremities not strongly differentiated.

Brachial valve moderately concave, greatest concavity near midvalve; ears flattened and defined by low, oblique fold. Sides sloping moderately medially; anterior slope short and less steep than lateral ones.

Pedicle valve interior with small stout teeth; thick apical callosity and short median septum continued anteriorly to about midvalve as low ridge. Lateral margins flattened.

Brachial valve interior with small excavate cardinal process and short, poorly defined prosocket ridges. Adductor dividing ridges not well developed. Anderidia not seen. Brevisseptum slender, extending as low ridge to antron. Visceral disc region marginally thickened in old adults, with narrow loop at anterior end. Margin with broad granulose flattening.

MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
AMNH 635							
151899a	8.4	7.2	11.0	11.4	11.9	3.7	2.8
151899b	8.6	?	11.5	11.5	11.0?	3.7	?
151899c	7.0	6.4	8.5	9.0	9.4	3.0	2.2
151899d	7.8	7.1	10.0	11.0	11.1	2.9	2.0
151899e	6.8	6.5	8.5	9.6	10.0	2.5	1.6
151899f	6.1	5.7	7.3	9.4	9.3	2.3	1.5
151899g	6.7	5.9	9.0	8.7	9.6	2.7	2.1
151899h	5.2	4.7	6.5	8.1	7.5	2.0	1.4
151899i	5.0	4.3	6.0	6.2?	7.4	1.8	1.2
151899j	4.7	4.4	6.0	6.9	6.9	1.8	1.4
151899k	4.0	3.6	4.8	6.6	5.7	1.5	1.1
151899k'	5.7	5.1	7.0	7.7	7.1	2.2	1.6
151899l	3.9	3.6	4.5	5.4	5.6	1.5	1.2
151899m	3.1	2.8	3.5	4.4?	4.5	1.1	0.7
153725b	7.4	6.0	9.0	10.9	10.5	3.0	1.7
(holotype)							

STRATIGRAPHIC OCCURRENCE.—Cherry Canyon Formation (Getaway Member), Bell Canyon Formation (Hegler, Pinery, and Rader members).

LOCALITIES.—Getaway: AMNH 21. Hegler: AMNH 635; USNM 731, 732a, 740c, 740d. Pinery: AMNH 398, 435, 437, 524, 537; USNM 725h, 725n,

733, 736. Rader: AMNH 397, 403, 410; USNM 725f, 725g, 725o, 740a, 740j.

**TYPES.**—Holotype: USNM 153725b. Figured paratypes: USNM 153725a, c, d. Unfigured paratype: USNM 153725e. Figured hypotypes: USNM 151899a, b, g; 153194a, b. Measured hypotypes: USNM 151899a–m, k'.

**DIAGNOSIS.**—Moderately transverse *Micraphelia* with the visceral region of the brachial valve strongly thickened and commonly strongly, and frequently extravagantly, spinose.

**COMPARISON.**—This species is separated from *M. subalata* by its more transverse outline and the lesser development of the cardinal extremities.

**DISCUSSION.**—As now identified this is a variable species and has been seen in all of the limestones of the Bell Canyon Formation except the McCombs and Lamar members. It is probable that other species are represented, but the lots from AMNH 635 and USNM 731 are the only ones containing an adequate number of specimens for study.

### *Micraphelia subalata*, new species

PLATE 493: FIGURES 24–37; PLATE 501: FIGURES 25–31

Small, wider than long, length about four-fifths of midwidth; hinge widest part, extended into small angular ears of about 80° to 90° but usually slightly

less than right angle. Sides generally straight and slightly oblique; anterior margin strongly rounded. Anterior commissure unfolded. Posterior margin with about 5 spines on each side. Surface smooth.

Pedicle valve evenly and fairly strongly convex in lateral profile, maximum curvature near midvalve; anterior profile strongly domed and with steep lateral slopes. Umbonal region strongly swollen and passing into greatly inflated midregion; umbonal slopes short and steep. Anterior slope long and steep. Ears depressed but convex; sulcus not developed. Interarea short, procline to anacline.

Brachial valve deeply concave and most concave in midvalve; posterolateral regions flattened and demarcated by abrupt change of slope into small ears; inner lateral and anterior slopes short but steep. Interarea short, hypercline.

Pedicle valve interior with thick apical callosity, short median septum continued anteriorly to about midvalve as low but fairly thick ridge. Teeth large.

Brachial valve interior with low, excavated cardinal process and short prosocket ridges. Adductor dividing ridges not strongly developed but continued anteriorly as row of spines. Aderidia slender and protruding. Brevisseptum strongly elevated and thickened, extending as low ridge to antron. Visceral margins strongly swollen, spinose and narrowly looped anteriorly.

#### MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
AMNH 410							
151890a	7.9	?	11.0	9.9	10.0	3.0	?
151890b	7.3	6.5	9.5	9.8	8.8	3.0	1.9
(holotype)							
151890c	7.0	6.5	9.0	9.6	9.1	2.4	1.5
151890d	7.3	6.6	9.0	10.8	9.2	2.8	2.0
151890e	6.7	5.9	9.0	9.3	8.4	2.7	2.1
151890f	6.5	5.6	8.5	8.9	8.6	2.8	2.2
151890g	6.4	5.7	8.5	7.9	8.1	2.5	1.8
151890h	5.7	4.9	7.5	8.0*	7.5	2.2	1.6
151890i	5.0	4.6	6.5	7.0	6.8	1.8	0.9
151890j	6.0	5.5	7.5	8.8	7.6	2.2	1.4
151890k	6.9	6.2	9.0	9.5	8.7	3.5	1.7

**STRATIGRAPHIC OCCURRENCE.**—Bell Canyon Formation (Hegler, Pinery, and Rader members), Capitan Formation.

**LOCALITIES.**—Hegler: AMNH 635; USNM 731,

732a, 740d. Pinery: AMNH 33; USNM 725h, 733, 748. Radar: AMNH 388, 397, 403, 404, 410; USNM 725f, 725g, 740a, 740i, 740j. Capitan: 748a.

**TYPES.**—Holotype: USNM 151890b. Figured

paratypes: USNM 151890k, 153726a–e, 153727a–h. Measured paratypes: USNM 151890a, c–k. Unfigured paratypes: USNM 151890a, c–j.

COMPARISON.—This species has a narrower and more compact form and better defined ears than *M. scitula*. The interior of the brachial valve is not so strongly thickened in adult specimens. No specimens have thus far been found with thickening in the brachial valve comparable to that of *M. scitula*.

#### Subfamily PLICHOCHONETINAE Sokolskaya, 1960

Usually small, strongly convex, costellate to costate Rugosochonetidae without fold and sulcus. Interior generalized.

Texas genus: *Rugaria* Cooper and Grant, 1969.

In the Glass Mountains this subfamily is represented only by *Rugaria*, a small costate genus found only in the Skinner Ranch Formation and rarely in the base of the Cathedral Mountain Formation.

#### Genus *Rugaria* Cooper and Grant, 1969

*Rugaria* Cooper and Grant, 1969:4.

Small, transversely subrectangular to transversely semielliptical in outline, hinge slightly greater to slightly less than midwidth; strongly concavo-convex. Ears small or not developed. Anterior commissure unfolded or with slight dorsal fold in young specimens. Posterior spines short, oblique.

Pedicle valve interior without strong sulcus on exterior. Interior with small teeth, short median septum with median ridge extending anteriorly to midvalve or beyond.

Brachial valve interior with excavated cardinal process and wide prosocket ridges. Adductor dividing ridges poorly developed; brevisseptum low, not continued posteriorly as far as antron. Visceral region not thickened.

TYPE-SPECIES.—*Chonetes hessensis* R. E. King (1931:61, pl. 9: figs. 21, 22).

DIAGNOSIS.—Resembling a somewhat depressed *Chonetinella* Ramsbottom, but not having a narrow and deep sulcus in the pedicle valve and a fold in the brachial valve, and having strong radii.

COMPARISON.—This genus suggests *Waagenites* Paeckelmann, from the *Productus* Limestone of Pakistan, but its ornament is much finer and it is not provided with the wide sulcus of that genus.

*Chonetinella* will not be confused with *Rugaria*

because the former is much more convex and is furnished with a prominent, deep sulcus on the pedicle valve, and is seldom as strongly costellate as *Rugaria*.

*Rugaria* does not have the herringbone pattern of ornament of the Russian genus *Reticulochonetes*. Compared with the type species of *Plicochonetes* Paeckelmann, the Glass Mountains genus is less strongly ribbed and differs considerably in details of the interior. The median septum and ridge of *Plicochonetes*, as indicated by the type-species, are short, not reaching to midvalve. In the brachial valve no median septum is developed and the adductor dividing plates are well developed, forming two divergent ridges just anterior to the prosocket ridges.

DISCUSSION.—This is an uncommon genus in the Glass Mountains and has been seen only in the Skinner Ranch Formation and Hess Formation (Taylor Ranch Member = "fossil bed" of King). In the latter bed it is fairly common, occurring loose in wash from a shale seam in a small area at USNM 702e. The specimens have been altered to a deep reddish-brown color.

#### *Rugaria crassa*, new species

PLATE 496: FIGURES 8–17

Small, rectangular in outline, hinge in well-preserved specimens slightly wider than midwidth; sides gently rounded but slightly oblique; anterior margin broadly rounded. Anterior commissure not folded in adults. Surface multicostellate, costellae coarse and numbering about 32 in adults about 8 mm long and about 16 in specimen 5 mm long. Number of spines on each side of beak on posterior margin not certain, probably 5.

Pedicle valve with unevenly convex profile, fairly strong in posterior half but somewhat flattened anteriorly and with maximum convexity near midvalve; anterior profile strongly domed. Umbonal and median regions strongly swollen and with steep lateral slopes. Median sulcus defined indistinctly in young specimens and posterior in position or indistinguishable in adults.

Brachial valve moderately concave, most concavity in posterior half of median part; posterolateral extremities demarcated by broad, oblique ridge, flattened and smooth posteriorly.

Interior details unknown.

## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 707a							
152100a	9.8	?	12.0?	?	13.3	3.5?	?
152100b	?	7.3	?	13.0?	11.5	?	?
152100c	7.8	?	10.0	10.7	9.6	2.4	?
152100d	?	6.0	?	10.0	8.4	?	?
152099	7.5	6.4	8.5	8.8*	8.0	3.2	1.4
(holotype)							

STRATIGRAPHIC OCCURRENCE.—Skinner Ranch Formation (Decie Ranch and Sullivan Peak members).

LOCALITIES.—Skinner Ranch (lower): USNM 711-p. Decie Ranch: USNM 707a, 729i. Sullivan Park: 722-1.

DIAGNOSIS.—*Rugaria* with strong costellae.

TYPES.—Holotype: USNM 152099. Figured paratypes: USNM 152100a-c, e, 153733, 153734. Measured paratypes: USNM 152100a-d. Unfigured paratypes: USNM 152100d, f-i.

COMPARISON.—This species differs from *R. hessensis* (R. E. King) in having much stronger costellae, in being slightly less transverse in outline, more convex, and in attaining a larger size.

DISCUSSION.—This is a very rare species in the Glass Mountains, a few specimens only having been taken from the thousands of pounds of the Decie Ranch Member broken up and also processed in acid.

*Rugaria hessensis* (R. E. King)

PLATE 496: FIGURES 18-25; PLATE 498: FIGURES 1-12; PLATE 499: FIGURES 70, 71

*Chonetes hessensis* R. E. King, 1931:61, pl. 9: figs. 21, 22.

Small, transversely rectangular in outline, hinge of well-preserved specimens forming widest part and extended into small rounded ears, anterior margin broadly rounded. Valves concavo-convex, the brachial valve having considerable depth. Anterior commissure unfolded to faintly uniplicate. Surface multicostellate, costellae numbering 60 or slightly more in large specimens (8 mm), but numbering about 30 in specimens 4 mm long. Posterior margin with 5 spines on each side of beak.

Pedicle valve with fairly evenly convex lateral

profile; anterior profile forming broadly convex dome. Umbonal and median regions swollen, with steep umbonal slopes but more gentle lateral slopes. Sulcus narrow, shallow, in some specimens barely visible, originating in umbonal region, usually becoming shallow or disappearing at anterior margin. Flanks moderately swollen. Costellae on umbo strong and direct but anteriorly bifurcating in three or four generations depending on size of specimen. One bifurcation taking place on umbo, one near midvalve and others anterior to midvalve. Interarea long, curved, slightly apsacline to anacline. Pseudodeltidium short, strongly convex.

Brachial valve fairly deeply concave, deepest part from umbonal region to midvalve; ears flattened and demarcated by oblique ridge and change of slope into concave midvalve. Fold scarcely visible and, when present, best defined at midvalve.

Pedicle valve interior with thick apical callosity and stout, short median septum continued anteriorly as low ridge to about midvalve. Muscle field subflabellate. Interior marked by radial rows of taleolae.

Brachial valve interior with broad, spreading cardinal process the median lobe of which bears two central ridges; cardinal process excavated anteriorly; prosocket ridges moderately strong. Brevisseptum reaching about to midvalve but not reaching the cardinal process and not thickened posteriorly. Lateral areas of visceral region not thickened; taleolae arranged in rows over entire surface.

STRATIGRAPHIC OCCURRENCE.—Hess Formation (Taylor Ranch Member), Cathedral Mountain Formation.

LOCALITIES.—Taylor Ranch: USNM 702d, 702e, 716o. Cathedral Mountain: 721u.

TYPES.—Lectotype: YPM 10820a. Figured paratypes: YPM 10820b, T10589. Figured hypotypes:



## MEASUREMENTS (in mm).—

	length	brachial valve length	surface length	hinge width	midwidth	height	thickness
USNM 702e							
152098a	8.1	7.5	11.0	10.0*	11.9	3.1	2.1
152098b	7.7	6.6	10.0	11.0	10.0	3.0	1.9
152098c	7.0	6.0	9.0	12.0*	10.3	2.8	1.6
152098d	7.6	6.6	9.0	10.7	10.0	2.5	1.7
152098e	7.1	6.4	8.5	10.6	10.0	2.5	1.2
152098f	7.3	6.3	9.5	9.9	9.4	3.0	1.9
152098g	6.9	6.0	9.5	9.8	9.6	2.8	1.9
152098h	6.2	5.6	8.0	9.2	8.2	2.4	1.4
152098i	5.5	4.5	6.0	8.2*	7.8	1.9	0.7
152098j	5.3	4.7	6.0	7.7	7.4	2.0	1.0
152098k	5.0	4.1	5.5	8.4	7.8	1.8	0.7
152098l	4.3	3.9	5.0	6.7	6.2	1.7	1.0
152098m	3.8	3.5	4.5	6.3	6.0	1.6	0.9
152098n	3.3	3.0	3.5	5.0	4.8	1.3	0.7
152098o	2.9	2.0	3.0?	4.5	3.5	1.1	0.6
152098p	8.4	7.2	11.5	11.0	11.3	3.3	2.0

USNM 152096a; 152097a–c; 152098a, b, f, j; 153747.  
Measured hypotypes: USNM 152098a–p.

COMPARISON.—This species differs from *Rugaria crassa*, new species, in having a more transverse outline, in having more numerous costellae and a less convex pedicle valve.

DISCUSSION.—This species occurs in a limited area along the mountain front for a few miles. It is common only at USNM 702e. A single pedicle valve was taken from the residues of USNM 721u, which has produced so many Skinner Ranch holdovers and other oddities.

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